RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM) DATABASE OF SHIP OPERATIONS COOPERATIVE PROGRAM

INTERIM REPORT

GULF COAST REGION MARITIME TECHNOLOGY CENTER

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ABSTRACT

The general objective of SOCP's RAM Database/SHIPNET is to provide a sound basis for improving the safety, reliability, cost-effectiveness and overall quality of marine machinery used onboard merchant vessels. This project is being conducted to establish an integrated RAM database to compile, process, analyze and disseminate field data from merchant ships. This field data collection to populate the database is a two step process. Initially, the data for past maintenance activities will be collected for target equipment and systems from existing maintenance records. Then, upon full implementation of the SHIPNET programs, data will also be collected for all SOCP defined critical equipment and systems. Other goals of the project include:

- Performance feedback for each SOCP participant
  Each participant will be able to see the machinery reliability and quality trends for their own fleet.
- Data sharing across SOCP for benchmarking
  Each participant will be able to compare the data for their fleet to the collective data for all SOCP members.
- Assistance in regulatory reform
  Data will be used by the regulatory agencies to revise current rules in order to reduce the regulatory burden where appropriate and to improve safety.
- Utilization of expert opinion in the continuous improvement process
  The experience of the chief engineer is a great resource and is incorporated into the improvement process.
- Equipment performance feedback for manufacturers
  Design and manufacturing deficiencies will be identified to improve reliability and cost effectiveness.
- Improvements in new ship designs
  The data will allow ship designers to consider and improve the operating cost, reliability and safety for the entire life of new ships.
- Development of an international network for data exchange
  An international network will be established to share reliability and safety data to learn from the experience of others.
- Compliance with the International Safety Management (ISM) Code
  The RAM Database/SHIPNET Project is designated to support a participating company's maintenance management system used to comply in a cost effective manner with some mandatory requirements of the ISM Code.
- Article 10.3 of the ISM Code states:
  "The company should establish procedures in SMS (Safety Management System) to identify equipment and technical systems the sudden operational failure of which may result in hazardous situations. The SMS should provide for specific measures aimed at promoting the reliability of such equipment or systems. These measures should include the regular testing of stand-by arrangements and equipment or technical systems that are not in continuous use."

SHIPNET is a computer based system of RAM data collection, evaluation and dissemination. This consists of a client server network consisting of several layered databases. Four applications are being developed for the project: Data Entry Program, DATE, Ship Performance Review Program, SHIPPER, Fleet Performance Indicator, SPIN, and Master Database Program, SHIPS' RAM. DATE and SHIPPER are currently being tested and at this stage, they have proven to be very functional although certain modifications may be implemented to accommodate each company's specific needs. Chief engineers' overall impression of DATE and SHIPPER have been both constructive and very positive. Up to now, the project was devoted to the development of structure and tools for RAM data collection. We have now reached a major milestone: the beginning of implementation. The SOCP RAM database project is seen as a significant improvement for failure data collection and reliability analysis in the US merchant marine industry.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The US shipping and shipbuilding industries are faced with ever increasing competitive pressure from other countries. Increasing regulatory requirements for safe vessel operation coupled with the ever increasing need for cost efficiency are the key drivers of today's maritime environment. U.S. maritime industry operators and ship builders must apply newly emerging technologies to confront the significant changes in ship management resulting from these pressures. The concerns of ship operators are the same, regardless of the cargo being carried or the market being served.

Reliability quantifies what fails and how often. It is the measure of the probability that an equipment or a system will perform a required function under stated conditions for a defined period of time. Availability identifies the most effective actions available to keep a system or equipment operational. It is defined as the probability that a system will be available and capable of performing its intended function at any random point in time. Maintainability is generally defined as the probability that an equipment or a system will be retained in or restored to a specified condition within a given period of time when maintenance is performed in accordance with prescribed procedures and resources.

Every ship operator wants to provide high quality service for their customers, while minimizing operating costs and maximizing ship safety and reliability. Reliability, Availability, Maintainability (RAM) characteristics of ship machinery are needed to implement reliability centered maintenance (RCM), and to help regulatory agencies in their efforts to improve ship safety with reduced regulatory burden. Development of RAM characteristics requires collection, processing, analysis, and sharing of data. In addition, there is a lack of coordinated feedback on the performance of safety regulations. Generally, regulatory agencies do not know if their standards increase the overall safety of vessels, or if regulations are inadequate.

1.1. History of RAM Database Development

Study for the establishment of a SHIPS' RAM Database was started by Dr. Bahadir Inozu as the recipient of University of New Orleans Summer Scholar Award (1991). Inozu also received funding from the SNAME T&R Program for a feasibility study on a RAM Data Bank for Merchant Ships (1992). The results of this study were published as a T&R report titled "Lessons Learned: A Study on Reliability, Availability and Maintainability Data Banks for Ships" in 1994 (1)(2).

A workshop was held in October 1992 for the U.S. shipping industry and selected government organizations to explore the concept of forming a Ship Operations Cooperative Program (SOCP), to identify the level of interest of these organizations in becoming members of the cooperative, and to identify project priorities which the SOCP could undertake. At this workshop, Inozu proposed the establishment of a RAM database for the US maritime industry.

Subsequent to the workshop, three ship operating companies, namely Sea-Land Service Inc., ARCO Marine, Inc., and Energy Transportation Group (ETG), as well as the National Oceanic and Atmospheric Administration (NOAA), and the Maritime Administration (MARAD), committed to become members. In April 1993, the SOCP was officially formed with the execution of a Cooperative Agreement by these organizations. As an industry led, cost shared, partnership between government and U.S. commercial vessel operators, the SOCP applies current technology to promote excellence in ship operations.

The main objectives of the SOCP are to improve:

- Efficiency
- Productivity
- Safety
- Competitiveness
- Environmental responsiveness of vessel operations

Initially, the SOCP decided to sponsor four projects, one of which was the RAM Database. Based on the consensus of the SOCP members this has emerged as the first significant project of the cooperative. Later, the American Bureau of Shipping (ABS), BP Oil Transportation Corporation, Bay Ship Management, Inc., Calhoon Marine Engineers' Beneficial Association (MEBA) School, Gulf Coast Region Maritime Technology Center (GCRMTC) at University of New Orleans (UNO), Interocean Ugland Management, Kirby Corporation, Lloyd's Register of Shipping, Marine Transport Lines, Military Sealift Command (MSC), The Nautical Institute, the United States Coast Guard (USCG), and U.S. Marine Management, Inc. joined the cooperative.

1.1.1. SOCP Sponsored Phase I

Phase I of the project focused on five major tasks: Survey of existing databases, development of data collection procedures, determination of analytical methods, development of rules and regulations for data bank operation, and initiation of international cooperation for ship RAM data exchange.

Various reliability databases were surveyed and examined, including the SRIC (Ship Reliability Investigation Committee) Database of Japan, SRF (Swedish Ship Owners Union - Sveriges Redare Forening) Database of Sweden, 3-M Database of the U.S. Navy, Government Industry Data Exchange Program (GIDEP), and the Offshore Reliability Database (OREDA). Operational procedures and format information of these databases were examined. This information was then used in subsequent tasks to develop data formats for the SOCP RAM database. Additionally, various advanced computer programs for optimizing ship operations and maintenance practices were obtained for review and evaluation. GIDEP and 3-M database searches were conducted to determine information availability and limitations. While there were RAM databases existing in the industry, information was not available at the level of detail desired by the SOCP to conduct detailed reliability assessments and comparisons for the shipboard equipment of cooperative participants.

Common data collection formats and procedures were investigated for ship machinery reliability data. Various performance indicators and RAM indices of existing databases were analyzed. Following this analysis, the SOCP Executive Committee established the RAM data entry fields and categories and selected RAM performance indicators for basic level analyses. SOCP initially considered modifying the Shipboard Automated Maintenance Management (SAMM) System, developed for the Military Sealift Command (MSC), to allow NOAA to collect data on a trial basis. However, after the evaluation of SAMM in depth, the SOCP decided to proceed with the development of a stand alone data entry application to efficiently collect equipment failure data. This application, called DATE, has now been completed. The development of custom interface programs to extract equipment/ship operational data that already exists in participating company information management system's in order to avoid duplication of data entry are currently being planned and specified.

Several international organizations were contacted to review the feasibility of international cooperation for the exchange of RAM data in the marine industry. These included ICMES (International Cooperation on Marine Engineering Systems), the Ship Research Institute of Japanese Ministry of Transport, Lloyd's Register, Det Norske Veritas, Ship Operations System (SHOPSY) of Germany, European Safety Reliability and Data Association (ESReDA), and others.

At the end of Phase I, the SOCP outlined the integrated RAM Database structure. The SOCP soon realized that a structure consisting of a single RAM database located at UNO was inadequate. To maximize the value to participants of collecting and sharing equipment RAM information, the SOCP decided to develop a client server network consisting of several layered databases. This approach would:

- increase the benefit to Chief Engineers right away if they maintain ship specific RAM data information onboard and have direct access to it
- give Chief Engineers immediate access to RAM data maintained onboard: a major factor motivating them to collect accurate data
- allow failure data coming from the vessel to be censored by operating companies prior to transfer to the master database. This requires a fleet RAM database at company headquarters.
- provide a fleet RAM database required at the company headquarters allowing a detailed analysis of company proprietary RAM data
- allow companies to review the data integrity prior to transfer to the master database

The SOCP soon realized that an efficient mechanism to collect, check integrity, analyze, transfer, share, and use RAM data to support qualitative and quantitative analysis of marine equipment and marine systems was required. This led to the development of the integrated RAM management system called SHIPNET. SOCP sponsored SHIPNET is a computer based system of RAM data collection, evaluation and dissemination. This consists of a network of RAM databases connected to the master database located at GCRMTC. SHIPNET has been formed to facilitate the efficient collection, analysis, and sharing of vessel life cycle data and to promote consensus building activities in the maritime industry.

SHIPNET is comprised of four related applications and a networking/communication system for data exchange and consensus building activities. These four applications are:

- A shipboard equipment Data Entry Program called DATE (**DAT**a **E**ntry Program) for use by vessel Chief Engineers to efficiently collect equipment failure information and compile it in a standard format. DATE can also be used by a vessel's Chief Engineer to view equipment nameplate, machinery history, and failure data for his vessel.

- A shipboard Equipment Performance Program called SHIPPER (**SHIP** **PER**formance Review) for use by vessel Chief Engineers to track and evaluate the reliability of equipment on their vessel based on the failure data compiled by DATE.

- A Fleet Performance Indicator Program called SPIN (**S**hips' **P**erformance **In**dicator) for use by shoreside superintendents to track and evaluate equipment reliability for one class of ship or for an entire fleet.

- A Ships' Equipment RAM program currently being developed to manage the master database at the Gulf Coast Region Maritime Technology Center (GCRMTC) located at the University of New Orleans (3).

1.1.2. SOCP / GCRMTC Sponsored Phase II and III

It was determined by the SOCP that Phase II of the project would focus on the development of DATE and SHIPPER. Phase II began on April 1, 1994 and ended on March 31, 1996. Phase III started on January 1, 1995 and ended on December 31, 1995. The Gulf Coast Region Maritime Technology Center at the University of New Orleans provided additional funding for the Phases II and III of the RAM database project starting in January, 1995.

SOCP phases follow the federal fiscal year, whereas GCRMTC follows the calendar year. Hence Phases II and III of the project overlap. The GCRMTC sponsored first year of the project corresponds to January, 1995 - December, 1995 period.

Major tasks of Phase II and III are summarized as follows:

1. Development of DATE and SHIPPER Versions 1.0 and 2.0
   - Code Development for Version 1.0
   - Testing Version 1.0 by GCRMTC and project participants shore side
   - Testing on board and obtaining feedback from chief engineers
   - Modification based on feedback leading to Version 2.0
   - Testing Version 2.0 by GCRMTC and project participants shore side
2. Site visits to headquarters and selected ships of project participants to examine the current machinery history record formats, and to identify the most efficient, effective and reliable approach to downloading existing failure and maintenance history into the RAM databases of SHIPNET
3. Selection of Critical Equipment and Systems for Data Collection - Part I

4. Name Plate Data Cross Referencing - Part I
5. Development of the Infrastructure necessary to support the RAM Database / SHIPNET
6. Pilot Data Collection from Log Books and Machinery History Records - Part I
7. Pilot Projects - RAM Analysis for Target Equipment
   - Main Condensate Pumps - Part I
   - Main Boiler Feed Pumps - Part I
8. Specification development for SPIN and SHIPS' RAM
9. Continuation of plan development for the expansion of SHIPNET on an international basis

Details of the above tasks for Phase II and III are included in the referenced sections of this report.

2. OBJECTIVES

The overall objective of SOCP's RAM Database/SHIPNET is to provide a sound basis for improving the safety, reliability, cost-effectiveness and overall quality of marine machinery used onboard merchant vessels. SHIPNET is a management system coordinating the collection, evaluation and dissemination of marine equipment failure data. This system consists of a set of integrated RAM (Reliability, Availability, and Maintainability) databases and a network connecting these databases to the master RAM database for the facilitation of electronic information exchange. SHIPNET is important to achieve the consensus building forum needed for safety and quality improvements in marine operations and for meaningful and prudent regulatory reform. RAM Database / SHIPNET is a structured approach to the continuous improvement of the RAM of marine equipment in vessel operations with an "*automated assessment engine.*"

The RAM Database has cross functional goals depending on the objective of the users. For ship owners / operators, it is designed as a cost effective, user-friendly, quality & safety management tool for continuous improvement. By using the latest information technology, the RAM database / SHIPNET is being established as a performance feedback system to improve ship machinery reliability and safety. By using the programs developed during the second phase of the project, ship operators can collect equipment failure and maintenance data and evaluate this data:

- To make meaningful comparisons of the reliability and maintainability of similar equipment to determine the cost-benefit of equipment renewal or replacement with a model of greater reliability.

- To rank in terms of criticality and prioritize the causes of equipment failures that can be repaired onboard in order to optimize the inventory of spare parts carried onboard and resources spent on training vessel personnel in equipment maintenance and repair.

- To improve the efficient use of maintenance resources onboard through the practical migration from a time based planned maintenance to a reliability centered maintenance system (RCM) where applicable.

For regulatory agencies, RAM Database / SHIPNET is being formed to provide qualitative and quantitative data for maritime regulatory reform and to support the assessment and validation of current regulations. The participation of marine equipment manufacturers and U.S. shipyards is currently being solicited to close the feedback loop. For shipyards / ship designers, the objective is to provide operational data to minimize total life cycle costs and to improve the safety and quality of new ships. For equipment manufacturers, SHIPNET is designed as a feedback mechanism for the improvement of equipment performance and design.

In addition, the International Safety Management (ISM) Code of International Maritime Organization (IMO) states that "*the company should establish procedures in SMS (Safety*

Management System) to identify equipment and technical systems the sudden operational failure of which may result in hazardous situations. The SMS should provide for specific measures aimed at promoting the reliability of such equipment or systems. These measures should include the regular testing of stand-by arrangements and equipment or technical systems that are not in continuous use." As a result, the RAM Database/SHIPNET Project is also designed to support a participating company's maintenance management system used to comply in a cost effective manner with the mandatory requirement of the ISM Code.

3. SCOPE

The RAM database/SHIPNET is designed to be a cross-functional and multi-purpose system for the improvement of the competitiveness, efficiency, productivity, safety and environmental responsiveness of vessel operations. Due to its complexity, a phased approach was adopted for the project. The primary concern is to satisfy the needs of the ship operators who will be supplying the data for the database. During the first phase these needs have been identified and were instrumental in shaping the database structure. Within this framework, the next phase will be to supply information to the regulatory agencies to be used in regulatory reform.

The next phase will also focus on equipment manufacturers to facilitate improvements in equipment RAM and on ship designers / builders to enhance the total life cycle performance of new ships. A contract has been awarded to Rockwell International to perform a feasibility study on expanding the structure of the RAM database and the SHIPNET decision support system to efficiently include shipyards and equipment manufacturers. Shipyards and equipment manufacturers are essential participants in SHIPNET in order to close the feedback loop which will promote continuous improvement of the reliability and safety of marine equipment and ships. This concept is consistent with the original objectives of the RAM database project and with the mission of the SOCP.

Currently, the scope of data collection is limited to critical equipment and system failures and the machinery history associated with these pieces of equipment and systems. However, inclusion of structural failures and hull maintenance is considered to be a natural extension of the database. A feasibility study of this concept is planned for the future.

Selection of critical equipment and systems for data collection has not yet been finalized. With the guidance provided by USCG and ABS, ship operators have determined their own preliminary critical equipment lists for data collection. These lists have been cross referenced to identify member equipment type and manufacturer matches. Finalization of the SOCP's first critical equipment list is currently underway. Each participant is refining their own company specific critical equipment lists and defining equipment boundaries.

Experiences from other successful reliability databases, such as OREDA, show that "in order to compare failures from different equipment classes installed" on board various ship types, "it is important to have a common definition of exactly what components or parts are to be included in one inventory for a given taxonomy code (4)." The equipment boundary defines parts associated with a generic item defined in the taxonomy. These parts are either considered to be essential for equipment function or sold by the manufacturer as part of the item. For example, in the OREDA database, the starter unit is included within the boundary for a Pump, whereas the fuel supply to the driver is not (See section 5.1.1, 5.6, and 5.7 for additional information on equipment/ component taxonomy and data exchange standards).

ETG, ARCO, Sea-Land, MARAD, ABS, USCG, NOAA and MSC decided to actively participate in the development of the RAM database. Three ship operators, namely ETG, ARCO, and Sea-Land have made a commitment to collect equipment failure data during the initial testing stages of the data collection software. Currently ETG operates 8 LNG vessels, Sea-Land Service, Inc., a subsidiary of CSX corporation, operates 93 container ships and ARCO Marine operates 10 tankers. More vessel operating company members of the SOCP are expected to join the data collection effort after the initial software testing stage is completed.

The scope of data collection from fragmented historical records will depend on the funding levels, quality and availability of data and priorities to be set during the execution of the strategic planning task for 1996. A plan for the data collection and analysis of existing records will also be prepared as part of the strategic plan.

The current scope of data exchange includes only the members of SOCP. Resources permitting, the SOCP plans to expand the scope of data exchange in the future to include international ship operators. This expansion is considered vital for the continued success of the RAM database project. However, for this task to be accomplished effectively, global RAM data exchange standards for ship machinery must be adopted. These standards are currently being developed (see section 5.4).

4. METHODOLOGY

This project is conducted to establish an integrated RAM database that compiles, processes, analyzes and disseminates field data from merchant ships for new failures, to retrieve existing machinery failure history data from records, to access international RAM databases, to investigate reliability and maintainability of existing shipboard machinery, to provide a basis for optimizing maintenance and ship building practices, and to promote excellence in ship operations.

The RAM database will be populated using DATE, which is a program to efficiently collect equipment failure and other machinery history information and compile it in a standard format. This program will be installed on board vessels of companies participating in the data collection effort. DATE can be used by a vessel's Chief Engineer to view equipment nameplate, machinery history, and failure data for his vessel. Figures 1 & 2 depict the program structure and information captured by the DATE program. The current version 2.0 of the data entry program, DATE, has four main entry options:

- Initial Setup - Ship Information and Equipment Operating Parameters
- Voyage Information
- Preventive Maintenance
- Corrective Maintenance

Figure 1 describes the information captured in the four main entry options. Figure 2 details the information stored for a corrective maintenance action.

Voyage information data entry captures Voyage Number and Vessel Operating Hours Underway, in Port, at Anchor and in Shipyard/ Lay-by modes. The Preventive Maintenance data entry module records any machinery history information not associated with a corrective maintenance action. The fourth main entry module captures corrective maintenance actions. This module captures equipment failure information essential to evaluate equipment reliability. Corrective maintenance actions are divided into various groups as shown in figure 2. Several details of the repair actions, such as delays, are also entered. (5)

For the coordinated review of equipment failure data, vessel personnel and management will use the PC-based programs SHIPPER and SPIN. SHIPPER is a program used by Chief Engineers to track and evaluate equipment reliability on his vessel based on the failure data compiled by DATE. SHIPPER will enable the Chief Engineer to sort and view the following performance indicators/RAM indices in three major categories as "the entire ship", "equipment class" i.e. all pumps, all compressors etc. and "individual equipment" for three failure classes namely critical, major and minor:

- Number of Failures (NF)
- Failure Rates (FR)

- Number of Preventive Maintenance Actions (NPMA)
- Vessel Mission Delays Caused by Failures (MD)
- Mean Time Between Failures (MTBF)
- Mean Time Between Critical Failures (MTBCF)
- Mean Time to Repair in Man-Hours (MTTR)
- Maximum Time to Repair in Man-Hours (Max TTR)
- Mean Logistics Delay Time (MLDT)
- Cumulative Repair Man-Hours (CRMH)
- Operational Availability based on Repair Man-Hours (A_1)
- Operational Availability based on Lapsed Time to Repair (A_2)
- Mean Lapsed Time to Repair (MLTTR)
- Average Spare Parts Cost (ASPC)

SHIPPER will also serve as a comprehensive vessel machinery history data display tool. The program will allow the vessel chief engineer to view the complete history of a piece of equipment including date placed in service, dates of major overhauls, failure history and equipment replacement history.

The RAM data collected from ships will be first sent to the headquarters of the shipping companies. The shipping companies will then be able to analyze their own data using SPIN which is an expanded version of SHIPPER. PC-based SPIN will enable ship operators to merge data from various ships of their fleet and to examine various combinations of performance indicators for problem detection and optimization of operating reliability. SPIN is designed for use by shoreside superintendents to track and evaluate equipment reliability for one class of ship or for an entire fleet. Shipping companies will forward their RAM data regularly to the master database at the Reliability, Operation and Maintenance Division of GCRMTC at University of New Orleans using SHIPNET and other channels. SHIPNET is a network to facilitate consensus building through the exchange of data and other files electronically using the Internet and other electronic transfer means.

A special workstation version of the SPIN Program, SHIPS' RAM, is currently being developed to merge, process, analyze and disseminate SHIPS' RAM data provided by various SOCP member companies. SOCP members will share this data for making decisions to improve the reliability and safety of their vessel's equipment and to reduce total life-cycle costs. The functional structure of the SOCP's RAM Database / SHIPNET is shown in figure 3.

The SHIPS' RAM program is currently being developed to manage the master database at the Gulf Coast Region Maritime Technology Center (GCRMTC) located at University of New Orleans. This program will allow equipment reliability data to be shared between different owner/operators participating in the SOCP sponsored data collection effort on a worldwide basis. At the request of an SOCP participant the SHIPS' RAM program will also facilitate the exchange of RAM data with other marine equipment reliability databases in existence.

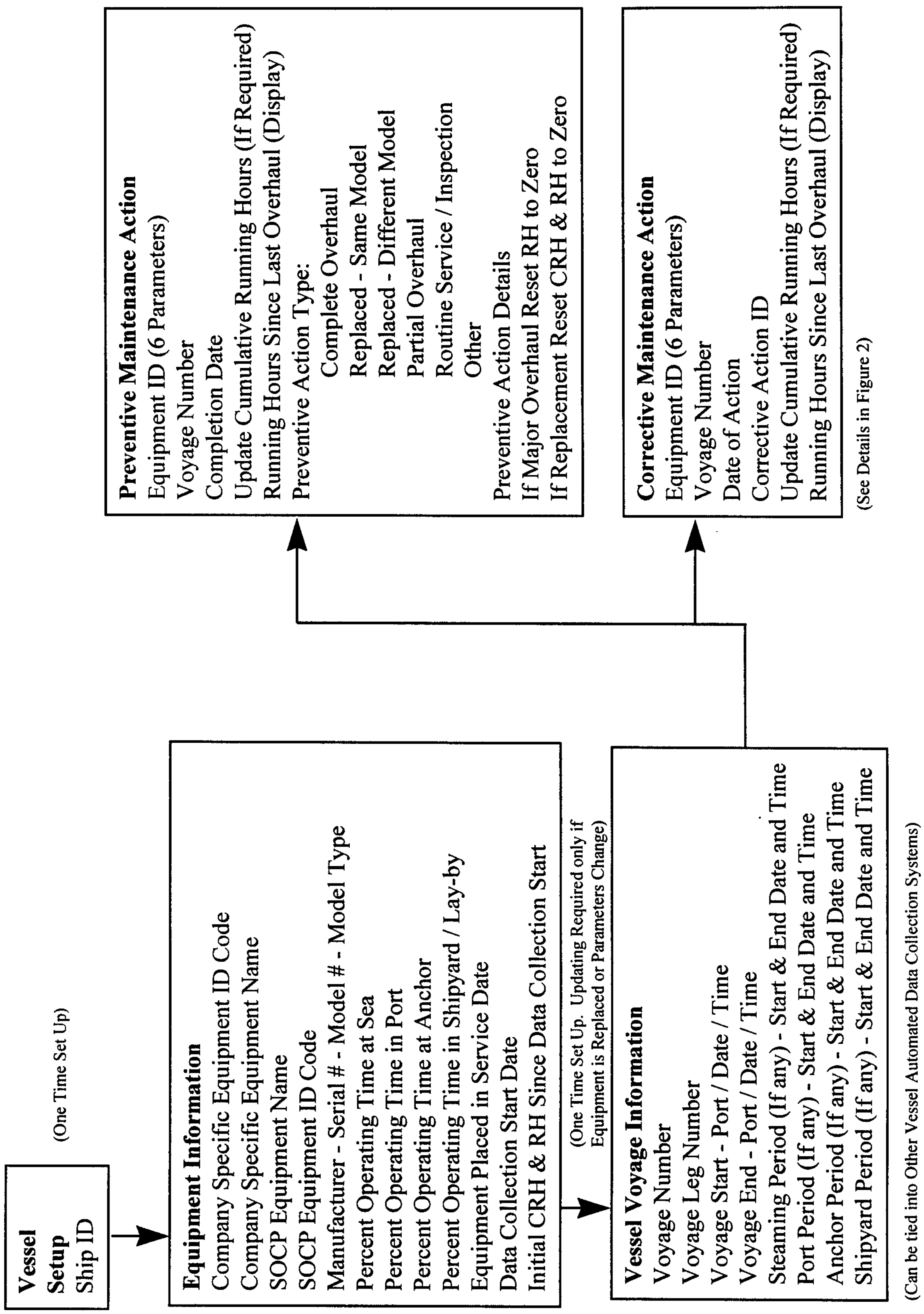


Figure 1 - DATE Program RAM Data Collection Fields

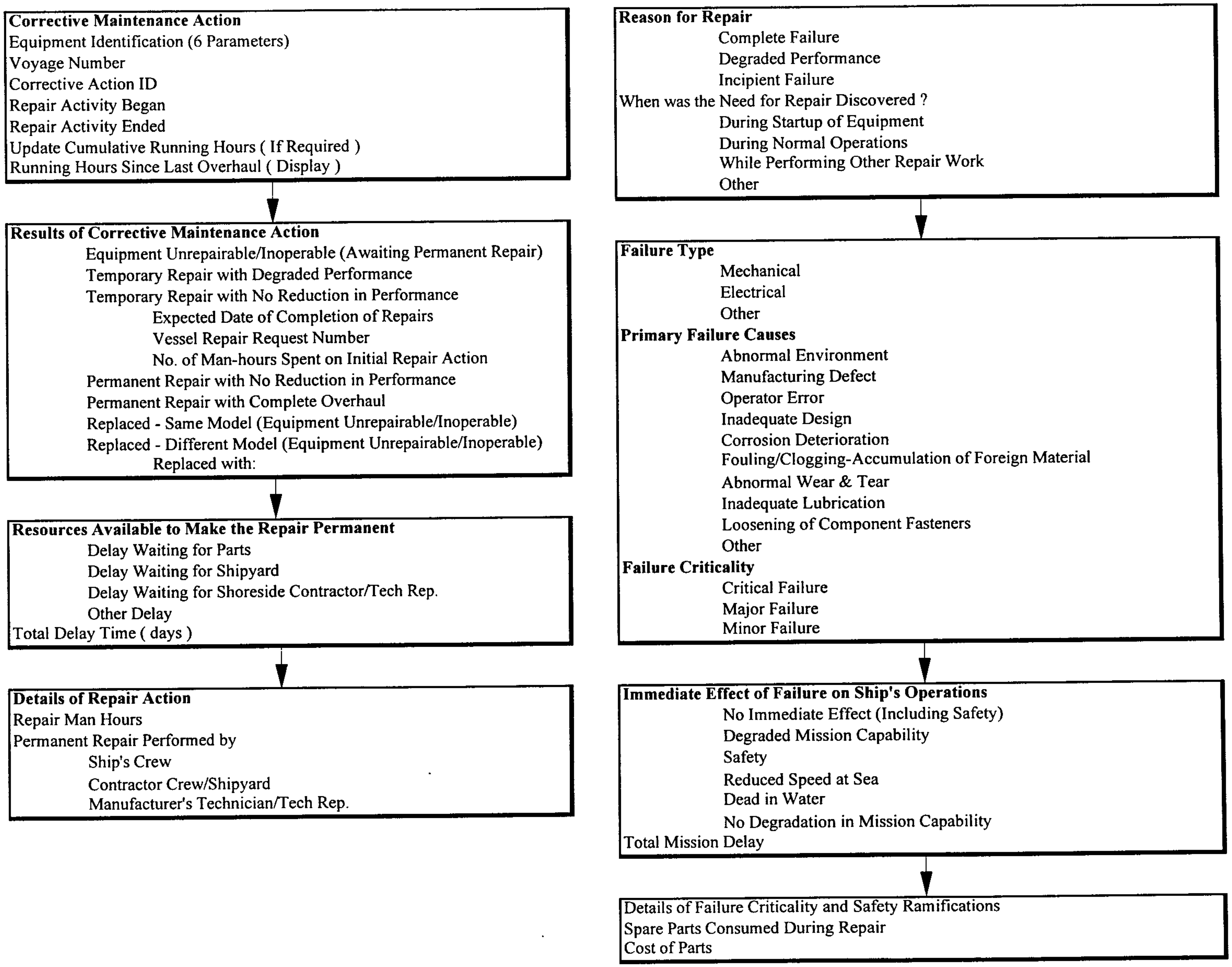


Figure 2 - Corrective Maintenance Action Details

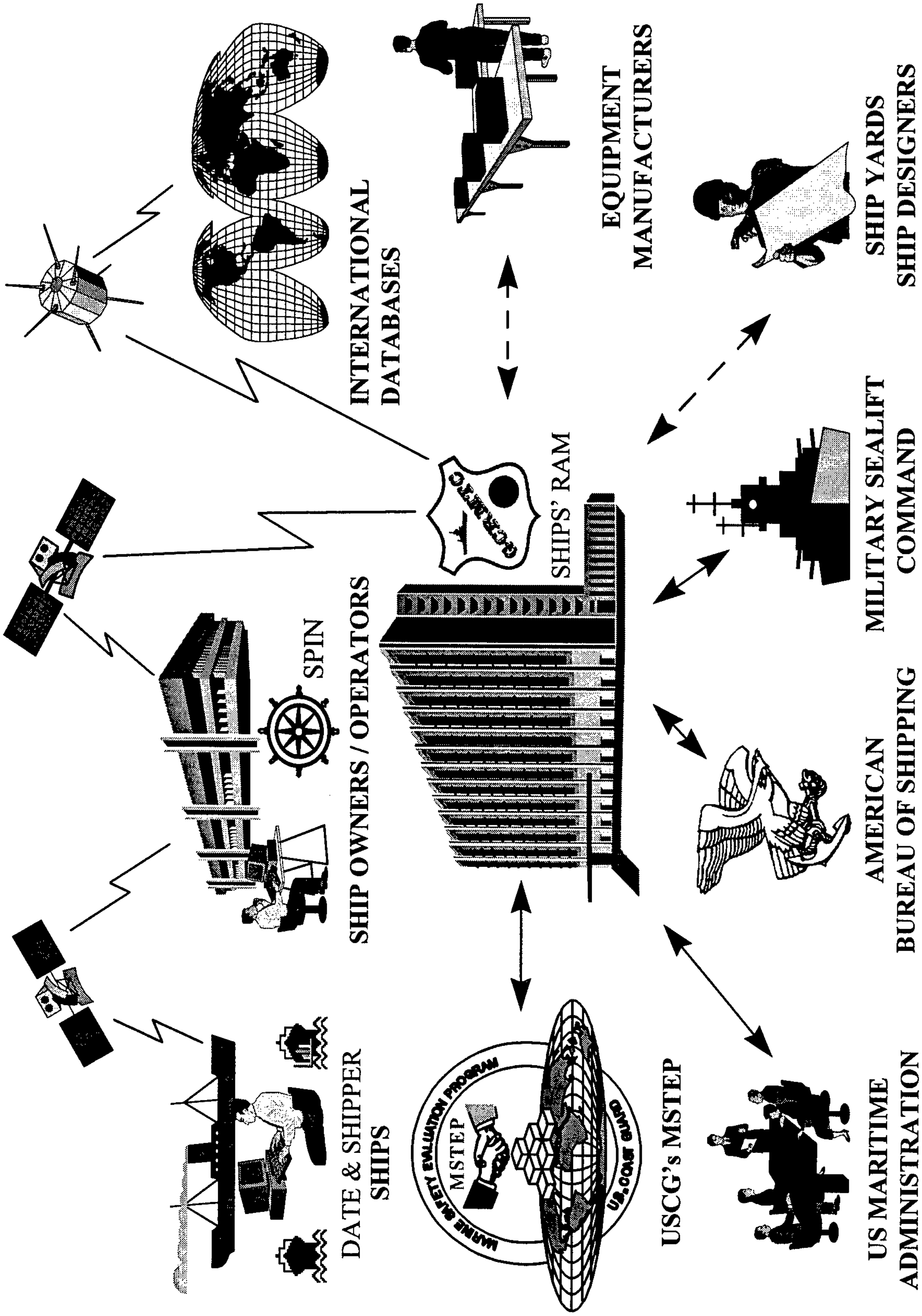


Figure 3 - Functional Structure of SOCP's RAM Database / SHIPNET

ETG, ARCO, and Sea-Land have been acting as Principal Industry Collaborators in the development of the database along with MARAD, ABS, USCG, NOAA and MSC. For the development of data collection and analysis programs, Bahadir Inozu developed the specifications for various programs. Then these specifications were refined by the SOCP project executive of the RAM database project, Mr. Peter G. Schaedel of ETG. Next, SOCP's executive committee gave the final approval for code development after further refinement of the specifications.

Actual code development was subcontracted. The first versions of the DATE and SHIPPER programs were subcontracted to Systems Exchange. The second versions of these programs were subcontracted to Diversified Computer Consultants (DCC). The UNO team was responsible for the testing of the Alfa and Beta versions of these programs under the supervision of the principal investigator on board selected ships, at the headquarters of participating companies, as well as at the Reliability, Operation and Maintenance Division of GCRMTC. The UNO team was led by Dr. Bahadir Inozu, and included Philippe Roy, Research Associate and Associate Coordinator and Graduate Research Assistants Hugues Gervaise, Guangli Yang, Veronique Molinari, Juan Manero, Iskender Gursoy and undergraduate research assistants / student workers, Robert C. Johns, Ivan Radovic, Todd Jacobs, Joyce Ladnier, Sonja Lamb, and Asli Agis. This team facilitated equipment data transfer into the ship specific equipment databases of the DATE program and performed cross referencing of equipment name plate data. In a pilot study, detailed performance and cost benefit analyses of target equipment were also conducted by the UNO team. The principal investigator was responsible for the coordination of all activities related to the project and communications with the rest of project participants.

Data transfer for participating members has been established for SHIPNET via a SUN Sparc 20 network using FTP (File Transfer Protocol) sites. The system was set up with the help of Dr. Bulent Yener, who currently assists in the management of the network.

The DATE and SHIPPER programs are PC based and were developed using Power Builder 4.0. For SPIN and SHIPS' RAM programs Oracle 7 database application software was used. SPIN works in a PC environment, whereas SHIPS' RAM is designed to operate in a workstation environment providing more options for data pooling and processing.As SHIPNET programs only perform a basic level data analysis, other programs are being used for more detailed studies. Advanced failure data and cost benefit analysis were performed using SAS, ReliaSoft's Weibull++ and MGA software A.C.S.L. in addition to the special programs developed in house using censored data analysis techniques and Maximum Likelihood Estimation. These detailed studies reveal the time dependence of the failure rates and their characteristics, including burn in and wear out periods if any. Basic administrative tasks, correspondence and some analyses are done with Microsoft Office Programs.

5. CURRENT STATUS AND DISCUSSION OF RESULTS

In this section, various accomplishments and current status of project tasks are presented.

5.1. DATE & SHIPPER Development and Database Population

First Versions (Version 1.0) of the Data Entry Program DATE and Ship Performance Review Program, SHIPPER were developed and tested at GCRMTC, ETG, Sea-land, ARCO Marine and PRC for three months. Based on the evaluations of version 1.0, the following modification/upgrade needs were identified and incorporated into DATE and SHIPPER Version 2.0 Beta:

- Extensions to voyage information to cover voyage legs, anchor events, and dry-dock/lay-by events,
- Removal of repair action dependence upon voyages (repairs can extend across multiple voyages),
- Ability to modify equipment operation rates under steaming, anchor, port, shipyard/lay-by conditions without losing previous rates,
- Equipment nameplate data expansion,
- Addition of flexible equipment class categories,
- Addition of initial operating hours for equipment,
- Temporary corrective repairs tracking as a folder until such time as the repair becomes permanent,
- Ability to enter all parts and costs used in the repair,
- Tabular vessel time line display from any starting point to any ending point,
- Ability for the chief engineer to override cumulative operating hours and use this value for future computations. Special treatment of equipment under temporary repair.
- Folder type displays
- Color coded graphical time line display
- Header & option & sequence changes
- Updating help function
- Standard Windows interface for Multiple Document Interface (MDI).
- Implementation of sorting capabilities on following windows: Voyage, Preventive Maintenance, Corrective Maintenance, Equipment and Equipment Class windows.
- Equipment ID searching capabilities on following windows: Equipment, Preventive Maintenance, and Corrective Maintenance windows.
- Print preview capabilities for all data entry windows.
- Implementation of calendar objects for date selection on SHIPPER report window.
- Functions for automatic adjustment of operation modes when user enters valid but inconsistent information.

Detailed descriptions of DATE and SHIPPER Version 2.0 Beta are given in Appendix A and B respectively. On board testing of DATE and SHIPPER Version 2.0 Beta and population of the

RAM database has begun. In addition, to accelerate database population growth and to identify the various formats in which the data is currently residing, pilot studies are being performed. These efforts include testing the SHIPNET software, obtaining feedback from chief engineers, examining the current machinery history record formats, and identifying the most efficient, effective and reliable approach to retrieve existing failure and maintenance history for entry into the RAM database.

Selected failure and maintenance histories from thirteen vessels have been compiled as part of the pilot testing studies. For different Program participants and for different ship types, various methods have been explored for entry of existing maintenance data. ARCO arranged for Chief engineer Matthew MacDonald to spend one week at the ARCO Center in Long Beach, California, to test the software and to enter data from fragmented records with Philippe Roy.

For Sea-Land, Philippe Roy traveled on the S/L Quality and Robert C. Johns traveled on the S/L Integrity on route from Charleston to Houston for software testing while identifying and entering data with the help of chief engineers.

For ETG, RAM data was compiled from the entire fleet for the 1985-1995 period for a specific pump type manufactured by two different companies. The data was entered using the SOCP's DATE program and forwarded to the RAM database via SHIPNET. A detailed data analysis has been started for these pumps. A summary of this on-going study is given in section 5.8.

Chief Engineers recommended the expansion of available preventive maintenance options to include three more fields: Partial Overhaul, Periodic Inspection and Other. These additions were made after approval of the SOCP. In addition, definitions have been discussed for planned vs. unplanned maintenance and preventive vs. corrective maintenance activities. Some chief engineers requested further clarifications regarding the classifications of corrective maintenance activities performed during scheduled maintenance.

Chief engineers have expressed a desire for inter-ship communication with regard to common problems and effective solutions, particularly when a company operates several vessels of the same or similar class. This would allow them to share and benefit from one another's experience. They would also be able to recognize equipment of questionable reliability or a major maintenance cost driver on their vessel using the analysis tools of the program SHIPPER. This analysis will trigger them to request the performance of other ships from their management. Management will use the SPIN program to analyze RAM data and respond to such requests for continuous improvement.

A lack of standardized data recording of participating SOCP companies presented challenges in the retrieval of historical data in several ways. First, the repair history data was not always available in the same format for all ships even within the same company. It was then necessary to explain to the chief engineer what input was required and to determine the best method for retrieving it. This issue was compounded by the fact that the chief engineers periodically change ships and, in some cases, are not completely familiar with a vessel's repair history and machinery log archives since it is kept in different formats on different ships. On a larger scale,

standardization would allow crew members who transfer from ship to ship within the company to retain a degree of continuity in their work.

As expected, some compulsory fields of DATE were not available in existing records. A sample comparison between the data fields of DATE and available data fields in current fragmented records is given in Table 1. Unavailable fields are either left blank or, preferably, the chief engineers' best estimate based on experience is entered. It is important that a field be left blank unless the chief engineer is confident that the estimate is accurate. To ensure accurate and credible data analysis results, the integrity of data entered is essential.

5.2. Customization of DATE via Company Specific Interfaces

Project participants will be collecting data in a standard format from four basic areas: voyage information, preventive maintenance, corrective maintenance, and equipment name plate data. In each area, data fields have been determined by the project participants. Currently, each project participant records activities using a variety of management programs and log books which contain a portion of the vital information required by the DATE program. One of the most important tasks for the RAM database project is to avoid re-entry of this data. Hence, we have started the development of DATE interface modules for each participant.

Each company uses a suite of programs to keep records. Some of these programs are commercial programs, such as FleetWorks and AMOS-D, and others are developed in-house. Preliminary analysis shows that for ARCO and Sea-Land we will need at least two interface modules to perform the automatic data transfer from various programs to DATE: one for voyage information, and another for the rest of the data. To transfer the data, participants will first run the interface modules to automatically transfer required data that has already been entered into other programs.

Identification of the DATE interface requirements has been initiated. In some cases company programs are currently being upgraded and, at the request of the companies, we have delayed code development of certain interface modules. We are currently examining the management programs being used by ARCO and Sea-Land. A comparison of matching fields for Sea-Land's AMOS-D and ARCO's FleetWorks is shown in Table 2 and Table 3. The table shows that the majority of the required data is not currently being entered. Through this expanded data entry, DATE will enable the monitoring of an expanded range of equipment performance. Hence, companies will be able to broaden the scope of their continuous quality and safety improvements.

Table 1 - A Sample Comparison between Data Fields of DATE and Existing Records

Fields of DATE	Ship A	Ship B
VOYAGE INFORMATION		
Voyage ID	Yes (Voyage abstracts)	Yes (Log books)
Start Port	Yes (Voyage abstracts)	Yes (Log books)
Start Date/Time	Yes (Voyage abstracts)	Yes (Log books)
End Port	Yes (Voyage abstracts)	Yes (Log books)
End Date/Time	Yes (Voyage abstracts)	Yes (Log books)
Operation Mode Date/Time	Yes (Voyage abstracts)	Yes (Log books)
PREVENTIVE MAINTENANCE		
Voyage number	Yes (Software)	Yes (Log books)
Voyage leg	Yes (Voyage abstracts)	Yes (Log books)
Equipment ID	Yes (Software)	Sometimes (Log books)
Equipment description	Yes (Software)	Yes (Log books)
Action date	Yes (Software)	Yes (Log books)
Action time	**No**	**No**
Running hours	Yes (Software)	**No**
Action type	Yes (Software)	Sometimes (Log books)
Action details	Yes (Software)	Yes (Log books)
CORRECTIVE MAINTENANCE		
Equipment ID	Yes (Software)	Sometimes (Log books)
Equipment description	Yes (Software)	Yes (Log books)
Voyage number	Yes (Software)	Yes (Log books)
Voyage leg	Yes (Voyage abstracts)	Yes (Log books)
Action start date	Yes (Software)	Yes (Log books)
Action start time	**No**	**No**
Action end date	Yes (Software)	Yes (Log books)
Action end time	**No**	**No**
Running hours	Yes (Software)	**No**
Results of action	Yes (Software)	Yes (Log books)
Expected completion	Yes (Software)	Sometimes (Log books)
Repair man hours	**No**	**No**
Vessel request #	**No**	**No**
Availability of resources	Yes (Software)	Yes (Log books)
Delay waiting for parts	Sometimes (Software)	Yes (Log books)
Corrective action details	Yes (Software)	Yes (Log books)
Location of the repair	Yes (Software)	Yes (Log books)
Individuals that performed the repair	Yes (Software)	Yes (Log books)
Repair reason	Yes (Software)	Sometimes (Log books)
Failure discovered during ...	Yes (partially in Software)	Sometimes (Log books)
Failure type	Yes (Software)	Sometimes (Log books)
Failure cause	**No**	Sometimes (Log books)
Failure criticality	**No**	**No**
Effect on ship operation	Yes (Voyage abstracts)	Yes (Log books)
Result of failure on vessel	Yes (Voyage abstracts)	Yes (Log books)
Spare parts' cost	**No**	**No**

Table 2 - DATE's Matching Fields for AMOS-D and FleetWorks

Fields to be filled out in DATE	Match with MMS FleetWORKS?	Match with AMOS-D?
VOYAGE INFORMATION		
Voyage ID	Partially	No
Start Port	Yes	No
Start Date/Time	Yes	No
End Port	Yes	No
End Date/Time	Yes	No
Operation Mode Date/Time	No	No
PREVENTIVE MAINTENANCE		
Voyage number	Yes	No
Voyage leg	No	No
Equipment ID	Yes	Yes
Equipment description	Yes	Yes
Action date	Yes	No
Action time	Yes	No
Cumulative Running hours	Partially	Yes
Action type	Partially	No
Action details	Partially	Yes
CORRECTIVE MAINTENANCE		
Equipment ID	Yes	Yes
Equipment description	Yes	Yes
Voyage number	No	No
Voyage leg	No	No
Action start date	Yes	Yes
Action start time	Yes	No
Action end date	No	Yes
Action end time	No	No
Cumulative Running hours	No	Yes
Results of action	Partially	No
Expected completion	No	Yes
Repair man hours	No	Yes
Vessel request #	Yes	Yes
Availability of resources	Partially	Partially
Delay waiting for parts	No	Partially
Corrective action details	Yes	Yes
Location of the repair	No	No
Individuals that performed the repair	Partially	No
Repair reason	No	No
Failure discovered during ...	No	No
Failure type	No	No
Failure cause	No	No
Failure criticality	Partially	No
Effect on ship operation	No	No
Result of failure on vessel	No	No
Spare parts' cost	Partially	Yes

Table 3 - DATE's Matching Fields for AMOS-D and FleetWorks (Cont.)

EQUIPMENT INFORMATION	Match with MMS FleetWORKS?	Match with AMOS-D?
Equipment ID	Yes	Yes
Equipment name	Yes	Yes
Manufacturer	Yes	Yes
Model number	Yes	Yes
Model type	Yes	Yes
Serial number	Yes	Yes
Memo field	No	Yes
Port operating hours %	No	No
Sea operating hours %	No	No
Anchor operating hours %	No	No
Dry-dock operating hours %	No	No
Initial Cumulative Running Hours	No	Yes
Initial Running Hours	No	No
Equipment installation date	No	Yes

5.3. SPIN and SHIPS' RAM Development

Based on the changes in the DATE & SHIPPER programs, the specifications for SPIN and SHIPS' RAM have been revised. A general preliminary framework of the SHIPS' RAM program for current participants was also developed. Common modules of SPIN and SHIPS' RAM programs have been designed by DCC (Diversified Computer Consultants). Code development for SPIN and SHIPS' RAM is underway using Oracle 7 (personal) desktop and workstation versions. Alfa versions of these programs are currently being tested.

SPIN/SHIPS' RAM will enable ship operators and GCRMTC to merge data from various ships, to track and evaluate fleet equipment reliability, and to examine various combinations of performance indicators for performance review and cost benefit analysis.

5.3.1. Fleet Database

SPIN/SHIPS' RAM will have a fleet database similar to the equipment database of DATE. The fleet Data Entry section of SPIN/SHIPS' RAM will have Names and ID's of ships in addition to specific ship information. Each company will give a code name for each ship for SOCP data exchange. The SOCP code name of the ship will be a separate field for the fleet data entry module of SPIN/SHIPS' RAM. In addition, a ship class identifier field will be available for sister ships. The development of ship groups or classes will be totally flexible within the program. The fleet database section will also have a "create ship group" option which will enable the user to select various ships from the pop-up menu and create a new group and name this group for data review and analysis.

5.3.2. Data Review with SPIN/SHIPS' RAM

All functions and reports of SHIPPER including "Time Line" will be available in SPIN/SHIPS' RAM. Currently, single and comparative display options are available for the same performance indicators that are available in SHIPPER.

By definition, MTBCF (Mean Time Between Critical Failures) is available for only critical failures. The rest of the performance indicators can be generated separately for all, critical, major, or minor failure categories. In addition, SPIN can generate these reports for the entire fleet, sister ships and user specified special groups.

For comparative ranking, SPIN has the flexibility for the selection of performance indicator combinations i.e. a user may want to compare FR's, MTBF's and ASPC's only. SPIN will give users the opportunity to choose from the pop-up menu to select any combination for data review. However, a default "all indicators comparatively" option is available as well.

SPIN is equipped with a folder type report display similar to SHIPPER. Users can create various reports ranking performance indicators individually or comparatively. The user can print or save these reports as well. In order to conduct cost benefit analysis, new parameters need to be created by transforming the fourteen standard performance indicators using company specific confidential algorithms. Hence, SPIN has the capability to create new performance indicators using the standard ones and the mathematical functions available in the software. For example, a shipping company may want to define a new performance measure called **Special Performance Indicator 1** (*SPI1*) which can be defined as $SPI1 = (aMTBF+bMTTR+cMD)/dMLDT$ where a, b, c, d are constants, and MTBF, MTTR, MD and MLDT are standard performance parameters. In other words, the user can develop custom formulas which give various weights to selected parameters and sort these parameters in terms of various ships, ship groups, equipment classes and individual equipment. The shipping company is able to give a custom name to the performance parameter as well.

5.3.3. Data Censoring and Storage for Master Database Feed

Special commands of the SPIN/SHIPS' RAM program censor and prepare the RAM data for transfer to the master database at GCRMTC. This transfer is in the form of retrieving (polling) the secured e.g. coded data from a specially reserved computer directory of each contributor by using the File Transfer Protocol tool called FTP. The master database software SHIPS' RAM is used to collect the RAM data from FTP sites of participants automatically and regularly. Alternatively, ship operators can choose to e-mail or mail the encrypted file to GCRMTC directly.

The "Export" command erases/blacks out confidential identifiers, i.e. actual name of the ship, serial numbers and saves censored RAM data with special SOCP identifiers for the regular master database feed. Fields to be censored are customizable by operating companies. Censorable fields include original ship names, all memo fields, voyage numbers, port names, company specific equipment names and ID's, equipment serial numbers, and repair request numbers.

5.3.4. Storage and Processing at RAM Database

The censored route files containing the equipment performance information for each ship will be loaded in the SHIPS' RAM program at the master database. Files that come in from the shipping companies will include data fields identifying the company code name and code names of the ships. Company files will be stored under separate directories e.g. individual directories for company A, B, C. The capability of SHIPS' RAM program to create ship groups enables master RAM Database staff to select any group containing various ships from different companies for data review.

The company code name, code names of individual ships, or any other data field subject to censoring by the program SPIN will not be released by GCRMTC without the written consent of the company that supplied the data. For their own vessels only, each participant may request any RAM performance data for a selected piece of equipment, equipment class, specific ship, group of ships or entire fleet at the basic or advanced processing levels. Participating companies may also request global RAM performance data for a special piece of equipment or equipment class. A specific piece of equipment would include manufacturer, type and model number.

For comparison purposes, companies can specify whether their own vessel data should be included in the calculations of performance indicators or not. Advanced processing includes estimates of failure time probability distributions to examine time dependency of failure rates, details of failure causes, etc. SHIPS' RAM will prepare the data files for advanced processing. Then, various programs available at GCRMTC will be used to analyze the data in detail as needed.

Example of Standard Data Request:

Select One
> Specific Equipment
> Equipment Class
> Specific Ship (Available for the requesting company's ships only)
> Selected Ship Group (Available for the requesting company's ships only)
Specific Equipment is selected above.

<u>STEP 1.</u> Enter period >>> From 1/1/89 to 7/1/94
<u>STEP 2.</u> Select desired equipment performance indicator(s) for report
Enter equipment selection (specific piece of equipment or equipment class):
SOCP Equipment ID: M150
SOCP Equipment Name: Feed Pump
Manufacturer: Warren (if equipment class desired - not required)
Model Number: 1002ASDE (if equipment class desired - not required)
Model Type: ER34 (if equipment class desired - not required)
<u>STEP 3.</u> Select One Data Group

A data request from a company may have two options: inclusion of its own company data and exclusion of the company data to allow benchmarking. Hence, this feature of the program will permit a company to compare the performance of its equipment with the rest of SOCP. However, SOCP participant A cannot request specifically the RAM data of SOCP participant B only, without getting special approval from participant B. In general, prior approval is not necessary to provide RAM statistics to an SOCP participant from either the complete SOCP pool or the comparative SOCP pool which excludes the requesting company's own data.

Average values for any of the selected performance measures will be displayed including company specific parameters for a specific piece of equipment or equipment class e.g. all pumps. The performance measures can be requested for any combination of ship groups. Reports generated using SPIN or SHIPS' RAM will indicate the database population used to generate the performance indicators.

5.3.5. Data Extraction Capability for Detailed Data Analysis

In the folder display of SHIPPER, the user has the option of displaying various performance indicators for a specific piece of equipment, an equipment class or the entire ship. These performance indicators are calculated for basic level analysis with special assumptions. These assumptions include constant failure rates and RAM indices shown as average values. A more accurate analysis of data requires advanced censored (suspended) data treatment techniques to estimate parametric probability density functions for failure and repair times. This analysis will be done at GCRMTC using special analysis tools. DATE captures all of the information needed to apply these advanced techniques. Hence, in order to conduct a detailed data analysis to identify probability density functions, the user will have the capability to download selected data from the tabular display report. This report includes the dates and times of various actions such as temporary repair with degraded performance, temporary repair with no reduction in performance, permanent repair, complete overhaul, replacement with the same model, replacement with a new model and others with special markers. However, this timeline display does not have cumulative and running hours display attached to these markers. For the SPIN/SHIPS' RAM programs, the user will have option of downloading time line markers with running hours, to analyze data with specialized advanced data analysis programs.

5.4. Pilot Studies for Demonstration

The RAM data to be collected will provide a very wide range of opportunities for continuous improvement in total life cycle cost effectiveness and safety. Typical applications of RAM data are shown in Table 4. (4) As part of strategic planning for implementation, each participant should select and prioritize the application areas of individual interest. The next step will be to select application areas of common interest to SOCP members.

Table 4 - Typical Applications of RAM Data

DISCIPLINE	EXAMPLE APPLICATIONS
DESIGN / ENGINEERING	**<u>AVAILABILITY STUDIES</u>** • Availability estimates (e.g. system performance simulation) • Design optimization (e.g. evaluate need for redundancy) • Equipment selection (e.g. select most reliable make/model) **<u>RISK ANALYSIS</u>** • Estimate probabilities of critical events • Estimate survival time for safety-critical items
MAINTENANCE / OPERATIONS	**<u>MAINTENANCE PLANNING AND OPTIMIZATION</u>** ***(Reliability Centered Maintenance)*** • Decide on maintenance approach, optimize maintenance intervals and the inventory of spare parts carried onboard • Monitor the reliability and quality trends, and analyze reliability characteristics (e.g. lifetime distribution, failure mechanisms) • Reveal weak designs that need modification or redesign • Feedback of data to manufacturers and engineering designers **<u>OPERATIONS</u>** • Demonstrate how operating conditions affect performance of equipment

Limited preliminary pilot studies have been started to demonstrate the immediate use of SOCP's RAM data for chronic failures of critical equipment including identification of the life time distributions, estimation of the reliability and availability of the equipment, examination of the failure rates and cost benefit analysis for the determination of the best repair/replacement policies.

In the first case study undertaken, ETG identified the main condensate pump as a potential target for reliability and life cycle cost improvement. Pumps from two different manufacturers were installed in identical service applications on board ETG's fleet. The ETG management asked the chief engineers to forward data for their main condensate pumps to their headquarters to be compiled and sent to the RAM database. RAM data for this type of pump was collected from vessel machinery history records for the 1985-1995 period. The compiled data was entered using the SOCP's DATE program and electronically forwarded to the RAM database via SHIPNET. A

detailed data analysis was conducted for these pumps. Failure time probability density functions have been developed using censored data analysis methods.

Reliability and failure rate functions were derived for the pumps of both manufacturers using parametric distributions (such as Weibull) as well as non-parametric ones. Estimations of Mean Time to Failure (MTTF) and reliability functions were developed both at the equipment and system level, since two of these pumps are installed on each vessel with one pump operating and one in standby during normal vessel operating conditions. Figure 4 shows a sample reliability plot at the component level for a single pump. Figure 5 shows the system reliability for a standby system of these pumps with special overhaul and operation procedures for different manufacturers. These figures show the difference of reliability functions at the component and system levels as well as the difference between the two pump brands. After the development of failure characteristics, a cost-benefit analysis study was conducted to examine various overhaul, upgrade and replacement options.

Manufacturers of both pumps were contacted and provided their own failure information for the study. After examining the failure data, one manufacturer suggested various material changes to avoid similar problems. The results of the study will be used to fully understand which option will be the most cost efficient over the projected remaining vessel service life.

Another case study was started for the main boiler feed pumps of ARCO. The failure data for the 1987-1995 period was compiled for this pump and forwarded to the RAM database where failure characteristics of this pump was analyzed. ARCO also requested a data search regarding the reliability of medium and low speed Diesel engines for a new ship that ARCO is planning to order. RAM database started the data search and provided failure information regarding different propulsion systems and manufacturers.

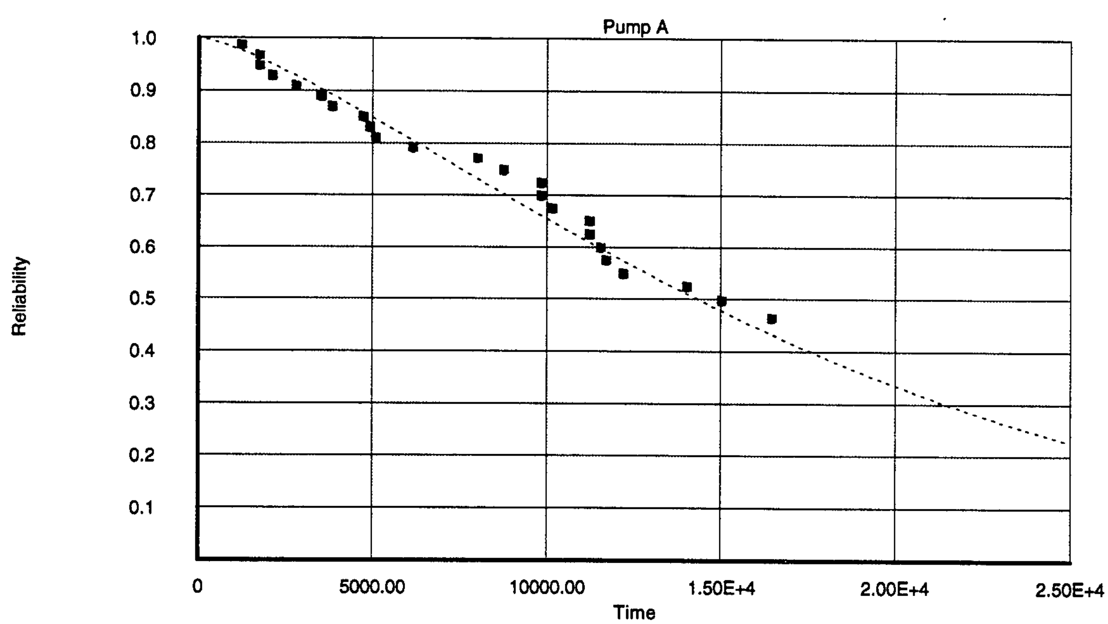


Figure 4 - Reliability of Pump A

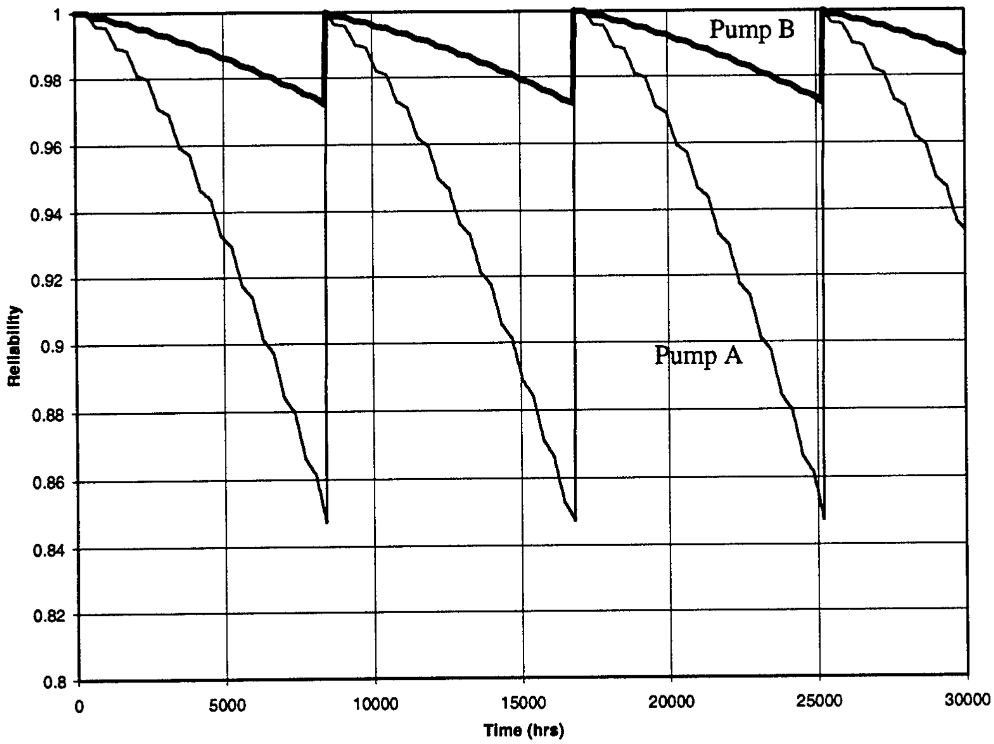


Figure 5 - Reliability of a Special Stand-by System

5.5. Identification of Critical Systems and Failure Criticality Levels

The purpose of this task is to start selecting target equipment and system categories, to identify failure modes for these target equipment and systems, and to clarify equipment boundaries and criticality levels. This task requires close cooperation with the USCG, ABS and the rest of SOCP as planned. ABS and the USCG approached this task in conjunction with their own in-house projects: the Marine Safety Evaluation Program (MSTEP) of the USCG and Rules 2000 of ABS.

In order to conduct an efficient reliability data analysis, equipment specific failure modes need to be developed for the SOCP critical equipment list. A failure mode is defined as the effect by which a failure is observed on the failed system. The failure modes describe the loss of required system function that result from failures. (4) As an example, some of the system level failure modes for pumps are defined by OREDA as follows:

- Failed To Start
- Failed While Running
- Significant External Leakage
- Low Output
- External Leakage
- Vibration

- Other (To Be Specified In Comment Field)
- Unknown

There are basically two types of critical equipment and systems. The first (Type I) are critical equipment and systems associated with the commercial viability of the ship. The second (Type II) are specifically associated with the safety of the ship and crew and the protection of the environment. Type I includes all critical equipment and systems that have a direct impact on the availability of the ship; handling and protection of the cargo; safety of the ship, crew, equipment, and cargo; protection of the environment; and efficiency of vessel operations and total life-cycle cost. Type II is a subset of Type I containing only those equipment and system associated with safety and environmental protection. Regulatory agencies are primarily concerned with Type II equipment, while ship operators are interested in Type I.

For safety critical items, both USCG and ABS were asked to provide their critical equipment and system lists. ABS provided a preliminary generic list as well as ship specific critical lists for the ETG, Sea-Land and ARCO fleets. ABS is revising its preliminary critical equipment and system list in accordance with its Rules 2000 project. Ship specific critical equipment lists of ABS were cross referenced for sister ships. Ship operators provided their company specific preliminary critical equipment lists which have been cross referenced and the differences between them are being examined. The SOCP has requested assistance from ABS to develop an equipment specific failure mode list for critical equipment once the critical equipment list has been finalized.

The USCG's most critical system list includes fuel oil system, lube oil system, air start system, AC generator, controls, cooling system and air intake & exhaust system. In the mean time, the USCG identified the Shipboard Electrical Power Generation System as its target for the Preliminary Hazard Analysis (PrHA) in accordance with MSTEP. PrHA included determination of criticality levels in different categories. A brief description of MSTEP and this PrHA is given in section 6.

5.6. Cross Referencing and International Data Exchange Standards

In order to conduct data searches for comparable equipment, eight traceable equipment nameplate data fields were established in addition to a large memo field in the equipment database of DATE. These fields are company specific Equipment ID and names, SOCP ID and name, manufacturer, model number, model type, and serial number. DATE is customized for each ship when this nameplate information is furnished. ETG, ARCO and Sea-Land provided sample nameplate data for their fleets. We have cross-referenced this data to identify matches of common equipment. Appendix C shows the first matches for the manufacturers of common equipment.

Since the SOCP decided to have a very flexible cross referencing capability for each piece of equipment, two types of equipment names and ID's were adopted: Company specific and common. The company specific names and ID's will be confidential and will only be used within the company while the common names and ID's will be used in the RAM database to facilitate the sharing of RAM information between SOCP members and, if appropriate, with other databases. Hence participating companies will not have to change their taxonomy for internal purposes. When they forward their data to the master RAM database, the SPIN program would

automatically block company specific names and ID's and send the data with the common SOCP names and ID's. In addition, when a user requests data from the master database, SOCP names and ID's will be used.

In the future, the SOCP envisions data exchange on an international scale. A global standard for marine equipment description is essential to conduct a meaningful analysis of data exchanged with other maritime related RAM databases. Our investigative efforts for the development of these standards showed that the International Standards Organization (ISO) approved the global Standard for the Exchange of Product Model Data (STEP - ISO 10303). Application protocols (AP) are being developed to implement this standard. AP226: the application protocol for the exchange of product model data of Ships' Mechanical Systems is currently being developed and led by an associate member of the SOCP, Lloyd's Register of Shipping. The scope of AP 226 includes the definition of equipment descriptors, definitions of the necessary parameters to measure, reliability, availability, and maintainability of ships' mechanical systems and the rest of parameters necessary for tracking a component's lifecycle / operational history.

Coordination with the STEP protocol requirements is being managed at the international level through existing formal liaisons between ISO/TC8 (Ships and Marine Technology) and ISO/TC 184 (Industrial Automation). Some SOCP members are represented on the U.S. Technical Advisory Group to ISO/TC 8, which is responsible for providing U.S. positions on such matters to ISO.

Active participation in ASTM gives individual SOCP members the opportunity for best representation in the U.S. marine industry on STEP and other matters. Currently, ASTM Committee F 25 (The American Society for Testing and Materials - Committee on Ships and Marine Technology) is preparing standards to be considered as the U.S. position in ISO.

The SOCP is reviewing various taxonomies for standard equipment descriptions and equipment ID's. Name plate data transfer to DATE for company specific critical equipment has been started for ETG, ARCO and Sea-Land ships. Refinement of the generic critical equipment list provided by ABS is still underway. The first phase of cross referencing this list with company specific critical equipment lists has been conducted. Ship specific critical lists of ABS have been cross referenced to identify matches and differences.

5.7. International Networking for RAM Data Exchange

The marine equipment designed and manufactured abroad constitutes a significant portion of the equipment installed on board the ships of the project participants. These types of equipment, as well as US made equipment, are also installed on board international ships. Hence, the SOCP is interested in learning the equipment performance experiences of foreign flag ship operators and sharing the equipment failure experiences of SOCP with foreign flag ship operators. As a result, the SOCP has initiated the formation of an International "Ship Network" to exchange equipment RAM information for the improvement of the safety and quality of ship operations worldwide. This initiative was started at the very beginning of the project due to its importance for the success of the RAM database project. Through direct contacts, other organizations have been

invited to participate in the establishment of the Ship Network. The SOCP wants to share their equipment performance information, specifically RAM indices, including some failure details with other ship operators and RAM databases around the globe in exchange for reciprocal access (6).

Various requests were received from international ship operators, regulatory agencies and the International Maritime Organization's (IMO) correspondence group on redundancy of machinery installations regarding access to the database and the SOCP's RAM Database groupware. ABS, an associate member of the SOCP, informed us that various International Ship Operators in principle agreed to collect RAM data on their equipment and share the data with SOCP's RAM Database in connection with the ABS Rules 2000 project. Various legal and administrative details are currently being investigated to facilitate international equipment data exchange. This includes changing the status of the SOCP to a non-profit organization.

SOCP envisions a basically open network where complete identification of the equipment including its manufacturer, model number, capability, and its global RAM history are shareable similar to the international networks of the airline and nuclear industries. The name of the ship where the equipment is installed and the name of its operator would be kept confidential. The SOCP recognizes the importance of the legal issues that could arise from the ownership of shared data. The technical problems of compatible equipment identification terminology and database structures also need to be overcome to implement the network. These are similar obstacles that the nuclear industry overcame in the formation of the international "Nuclear Network" and the electrical industry in Canada overcame in the formation of Equipment Reliability Information System of the Canadian Electrical Association. The legal ramifications could affect owners/operators, flag-states, shipyards and classification societies. The SOCP believes that the demand for higher safety, productivity and better quality will eventually overcome these legal, cultural, and technical obstacles (7)(8)(9)(10)(11)(12).

The SOCP's SHIPNET initiative was also discussed at ICMES TC-1 (International Cooperation on Marine Engineering Systems - Technical Committee on Availability, Reliability, Maintainability and Safety) meetings held in October, 1994 in Trondheim, Norway, and in May 1995 in Madrid, Spain. A paper entitled "SOCP's RAM Database/SHIPNET: A Cross Functional Network for Total Life Cycle Cost and Safety Decision Support" was accepted for presentation at ICMES'96: Safe and Efficient Operation of Ships - New Approaches for Design, Operation and Maintenance, to be held on June 13-14, 1996 in Trondheim, Norway. Co-authors of this paper are Bahadir Inozu, Peter G. Schaedel and Zbigniew J. Karaszewski.

5.8. Tasks for 1996

Software development, testing and implementation has been and remains our highest priority. As the program continues to develop, new needs emerge as participants' applications for RAM data, systems engineering and risk based technologies evolve. The first two tasks are directly linked to software development. As the scope of the database has expanded a greater emphasis has been placed on short and long term strategic planning. As the database begins to be populated with equipment failure information, three key areas have emerged that users will have to be trained in.

These include training in systems engineering, reliability centered maintenance, and risk based technologies.

5.8.1. Task One: Testing of First Year Data Collection & Review Software and Second Year Master RAM Database Software

SHIPNET groupware and the company specific data entry interface modules will be tested, upgraded, implemented following trials on-board ships, on-shore and at GCRMTC.

5.8.2. Task Two: Population of RAM Database, Analysis of RAM Data and Creation of SHIPNET Help Desk

Data Entry from Ship Log Books and Machinery History Records will continue to accelerate data population growth. A SHIPNET communications help desk will be established to respond to the immediate RAM data and literature search needs of SOCP and to facilitate electronic information exchange, dissemination and consensus building among SOCP members. Limited preliminary pilot studies will be conducted to demonstrate the use of SOCP's RAM data for chronic failures of critical equipment and systems including identification of the life time distribution, estimation of the reliability and availability of the equipment, examination of the failure rates and determination of the best repair/replacement policies. Identification of failure modes will be coordinated for target equipment in cooperation with the USCG, ABS and other project participants. Common equipment will be identified for comparative analysis. Initiation of ship equipment life cycle modeling is also planned.

5.8.3. Task Three: SEM Training

Rockwell International has been contracted by GCRMTC to conduct a feasability study of expanding the scope of the RAM database to include US Shipyards and marine equipment manufacturers. As a parallel effort, Rockwell will provide the SOCP member companies participating in RAM data collection with training on the Rockwell System Enterprise Methodology (SEM). SEM supports enterprise integration activities by providing a structured technique for developing, managing, and integrating information resources. It's aim is to translate user needs into an operational information systems and assets to promote data exchange, management, and use.

The enterprise integration enabled by the SEM should not be thought of as just an improvement project or a network of computing systems, but rather as a set of philosophies, concepts, and values that direct the ongoing management process of bringing business processes, information, organization, and technology into alignment with specific performance objectives. The intent is to increase the quality, value, and flexibility of the RAM database to participants, while reducing the time and cost associated with getting that value. (13)

The SOCP team will receive training with the following objectives:

(a) Familiarization with SEM Process, and (b) Familiarization with the project technical approach. This training will be performed at a workshop facilitated by the Reliability, Operation and Maintenance Division of GCRMTC at University of New Orleans.

5.8.4. Task Four: Strategic Planning

The SOCP will give guidance and oversight to Rockwell Maritime on when and how the SEM methodology should be adapted and applied to the maritime industry. With the SEM process understood, Rockwell will lead a business process analysis task for determining a common RAM Database / SHIPNET vision for the SOCP. This analysis will result in the development of a RAM Database / SHIPNET vision statement and set of functional objectives.

Rockwell shall conduct a workshop session that will include representatives of SOCP to plan the application of SEM Methodology to the RAM Database / SHIPNET. The functional objectives will be documented in one or more Units of Functionality (UoFs). Each UoF contains a set of five statements that identify and describe a desired need. The UoFs Provide a mechanism for maintaining traceability between user requirements and system design specifications. With the vision and accompanying UoF's defined, Rockwell will prioritize and group together the Uof F's to define modules for implementation within the SOCP's RAM Database / SHIPNET environment. The implementation modules, or Build Cycles, will define the set of capabilities that will be satisfied by each iteration of the SEM. A quality assurance plan will be developed to ensure data accuracy.

5.8.5. Task Five: Build One Requirements Definition

Based on the scope of the first implementation cycle specified determined in Task Two, the system requirements capture process shall be initiated. The focus of file requirements capture is on the information requirements for the database. In this information requirements extraction procedure, the desired capabilities will be translated into application object information requirements. The information requirements shall then be used to create the Build One Application Reference Information Model (ARIM).

The set of interrelated objects making up the Build One ARIM will be defined from the process input and output information requirements (query mappings, documents and databases) that are within the scope of the Build. These needs shall be extracted from the capability statements of the Build One Uof's and through requirements capture sessions held with SOCP team personnel.

When funding resources and strategic priorities permit, additional modules of the master database software will be developed and current modules will be modified implementing the build one information data models. This task overlaps almost completely with the tasks of the database expansion contract of Rockwell.

5.8.6. Task Six: International Ship Network Development

Establishment of the International Ship Network will be continued to share RAM data globally for improved ship safety and to acquire RAM data from foreign equipment manufacturers when

appropriate to do so. The SOCP member companies are currently reviewing the best method for them to participate, either as a group or as individual companies, in the development of RAM, Total Life Cycle and Safety related STEP Application protocols to facilitate meaningful equipment failure data exchange and benchmarking.

5.8.7. Task Seven: Development of Interfaces with Regulatory Agencies

The USCG's Marine Safety Evaluation Program (MSTEP) / RAM Database Interface Plan will be implemented in cooperation with USCG. In addition, ABS Rules 2000 / RAM Database Interface Plan may be initiated if agreeable to both the ABS and the SOCP.

6. MARINE SAFETY EVALUATION PROGRAM (MSTEP)

In the current environment of dwindling resources, the U. S. Coast Guard (USCG) wants to reform to become more efficient by implementing a systems approach to marine safety determinations. As a result of this Regulatory Reform, the USCG is embracing Risk Based Technology (RBT) and the IMO's Formal Safety Assessment (FSA) initiative. USCG feels that the use of RBT is viable to make better decisions with fewer resources. Hence, in 1993, the USCG has established the Marine SafeTy Evaluation Program (MSTEP) based on the use of RBT.

The MSTEP initiative is being promoted by the USCG to conceptualize, develop, test, apply and disseminate a new approach for determining the safety of marine systems while reducing the regulatory burden being imposed by obsolete management systems. MSTEP differentiates itself from other safety assessment programs by promoting the use of systems engineering methods to support safety determinations.

The primary objective of MSTEP is to improve the current process of assessing the safety of marine systems, subsystems, and components that fall within the USCG's regulatory domain. Improving this process will provide a basis for identifying reductions in the regulatory regime while enhancing the competitive position of the U.S. maritime industry.

The methods that evolve under MSTEP will be implemented through the Marine System Assessment Module (MSAM). MSAM employs proven risk-based technologies and assessment methodologies used in the nuclear, chemical, and other industries operating complex engineered systems, and adapts them to the maritime environment. This module adopts state-of-the art technology for performing system safety assessments and provides a logical basis on which to develop safety criteria. MSAM is envisioned to be a semi-automated system for performing a variety of safety-related assessments. The initial emphasis in developing MSAM will be to demonstrate the viability of the concept. This will be accomplished by developing and testing a prototype capability. After proof-of-concept is established, the system functionality will evolve through a series of releases. In parallel, a coordinated effort will made to populate the knowledgebase needed to support the system.

To demonstrate the utility of the MSTEP risk-based approach as a methodology for determining alternative regulatory compliance, various candidate systems were considered for a proof-of-concept. The basic selection criteria for a candidate system was that the system must have a high cost-to-safety ratio, and the system must be a good representative of all other applicable systems. The MSTEP team chose the cargo hold lighting system installed aboard the US Maritime Administration (MARAD) reflagged Cape H and Cape W class RO/RO vessels. This system was chosen because of the high cost to replace a significant number of fixtures installed in order to achieve compliance with Federal regulations and class society rules. The analysis of the cargo hold lighting system set out to answer two essential questions:

1. Is the current hazardous location classification of the cargo spaces consistent with the true safety risks ?
2. Are the currently installed lighting fixtures adequate if the cargo space were to be reclassified?

The evaluation concluded the following:
1. There is a risk of personal injury due to inadequate emergency lighting for safety inspections
2. The likelihood of an explosion (with current lights providing an ignition source) is low.

This conclusion is based on the amount of fuel that could be spilled and its ability to reach lower explosive limits at the location of the current lights. Thus, reclassification of the compartments in order to retain the current lights is appropriate.

The MARAD lighting system analysis resulted in a savings of over $7,000,000 for five ships. Operational, intrinsic design, and other risk mitigating features were given "credit" and provided the basis for the decision to retain the existing lights. Use of the MSTEP approach illustrated that when a system is analyzed in the context of its total operational and design environment, alternatives to strict adherence to the regulations may be achieved with the potential for significant cost savings without sacrificing personnel safety, vessel safety or property damage goals.

6.1. Building the Bridge between RAM Database and MSTEP

One of the main goals of the SOCP's RAM Database / SHIPNET is to provide qualitative and quantitative equipment and system performance information to regulatory agencies to improve ship safety and reliability with reduced regulatory burden. The RAM Database is designed to be a foundation for efficient utilization of complex decision analysis tools, such as risk based technology, using industry accepted RAM parameters. As a participant of SOCP, the USCG is developing an approach to incorporate the SOCP's RAM database / SHIPNET in its Marine Safety Evaluation Program (MSTEP). The RAM Database / MSTEP interface plan has been developed.

On December 12-13, 1995, USCG organized an RBT workshop. All working groups of this workshop emphasized the need for qualitative and quantitative RAM data for successful implementation of the RBT.

The immediate link between RAM database and MSTEP is via the Preliminary Hazard Analysis (PrHA) of MSAM. PrHA is mainly a qualitative method which addresses the following holistic safety attributes:

- Application of systems engineering approach
- Life-cycle and information related to it
- Product breakdown structure
- Human element both at the equipment and system level.

The Risk Based Technology (RBT) approach uses a top-down approach to define hazards and accident scenarios. RBT is based on answering three fundamental questions namely:

1. What can go wrong ?
2. What is its likelihood ?
3. What are the consequences ?

A rank-ordered list of major risk contributors is developed, and thereafter, efforts and resources are concentrated on systems with the highest consequences and frequency of failure. Thus, RBT provides a logical basis for balancing risk and economic impact in the development of regulations or the evaluation of alternative compliance strategies.

For the present proof-of-concept, a team of safety analysts and ship systems experts performed a Preliminary Hazards Analysis to demonstrate the RBT application first for the Cargo Lighting System as mentioned in section 6 and then for Ship's Service Diesel Generator System (SSDG). For both studies, a qualitative safety assessment was first performed based on the safety related accident scenarios. For the SSDG study, the consequences of various scenarios were examined and ranked in five severity categories and in five classes. These categories included the Ship (S1), its Operability (S2), Maintainability (S3), Personnel Death / Injury (S4) and Environmental Impact (S5). The criteria for consequence categories and its classes are shown in Table 5. Protective features for each accident scenario and recommendations were identified. The likelihood for each scenario was also assigned based on expert opinion and data. Four likelihood categories used in the study are shown in Table 6. SOCP's RAM Database / SHIPNET conducted data searches and provided various qualitative and quantitative failure analysis reports from its library for the study.

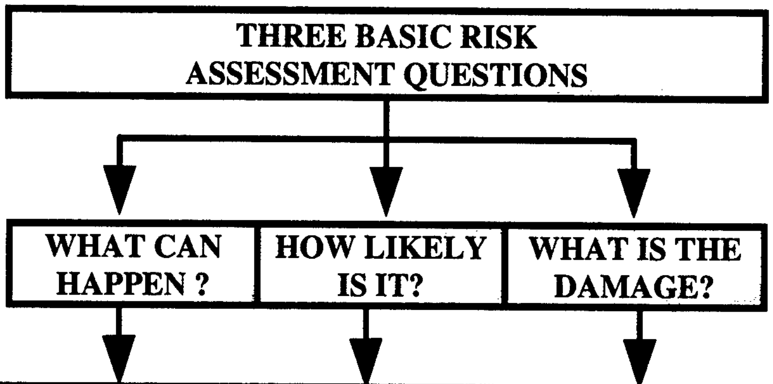
The MSTEP core team recognizes the importance of concurrent use of both qualitative and quantitative analysis for the accomplishment of its goals. In its pilot studies, investigations started with qualitative analysis which is generally the standard procedure used in other industries. Further refinement of the results requires additional quantitative analysis. The relation between qualitative and quantitative analysis is shown in Figure 6 (14). The role of SOCP's RAM Database / SHIPNET in MSTEP is expected to be the prime provider of references in ship reliability, availability, maintainability and operability, needed for both qualitative and quantitative analysis and to facilitate constructive communication between the MSTEP team and all stake holders using electronic questionnaires via Internet and other channels. The overall environment for MSAS is shown in Figure 7. The functional structure of the RAM Database / SHIPNET and MSTEP Interface is shown in Figure 8.

Table 5 - Consequence Categories

Categories	Ship (S1)	Operability (S2)	Maintainability (S3)	Personnel Death/Injury (S4)	Environmental Impact (S5)
A	Loss of Ship > $10,000,000	Loss of Service Power in the Ship	> 96 Hours	Fatalities	> 1,000 Gallon Spill > $100,000 Damage/Fine
B	Major Damage > $10,000 - $10,000,000	Loss of Hotel, Cargo, Industrial, and Auxiliaries	48-96 Hours	Loss Time Injuries	10 - 1,000 Gallon Spill > $10,000 - 100,000 Damage/Fine
C	Minor Damage >$1,000- $10,000	Loss of Hotel, Cargo and Industrial	10-48 Hours	Minor Injuries	1-10 Gallon Spill >$1,000- $10,000 Damage/Fine
D	<$1,000	Loss of Cargo and Industrial	<10 Hours	No Injury	<1Gallon Spill <$1,000 Damage/Fine
E	No Damage	No Impact	No Impact	No Injury	No Impact

Table 6 - Likelihood Categories

I	Likely. May occur as often as once in an operating year in any similar ship
II	May occur. Frequency between one a year and once in 10 operating years or at least once in 10 similar ships operated for one year
III	Not Likely. Frequency between once in 10 years and once in 100 operating years or at least once in 100 similar ships operated for one year.
IV	Very unlikely. Frequency between once in 100 years and once in 1,000 years or at least once in 1,000 similar ships operated for one year.



Analysis Method	**Scenario Definition**	**Scenario Quantification**	**Consequence Assessment**	**Form Of Results**
Qualitative	Systematic Lists	Judgmental Estimates Of The Frequency Range	Judgmental Estimates Of The Damage Level	Ranked Scenario Lists
Quantitative	Comprehensive Logic Models	Scenario Frequency And Confidence Level Calculated	Damage Magnitude And Confidence Level Calculated	Risk Curves With Ranked Contributors

Figure 6 - Relation between Qualitative and Quantitative Analysis in Risk Based Assessment

The information needed to support MSTEP in the long term is enormous. Since much of the information needed is not currently available in digital form, expertise is needed to efficiently and effectively collect this information from documents and directly from end users. Various analytical, groupware and software tools for consensus building such as Lotus Notes and INFORUM are currently being examined and tested (15).A strong and proven analytical tool for consensus building in risk regulation is the Multi-attribute Utility Theory. In many areas, Multi-attribute Utility Techniques (MAUT) have been extensively used to identify public values in the regulation of specific risks and then to facilitate the development of regulations based on risk assessment adequately addressing the concerns of all stake holders with conflicting objectives. Edwards and Winterfeld describe the MAUT and successful implementation of its tools in risk regulation with case studies in (16)(13).

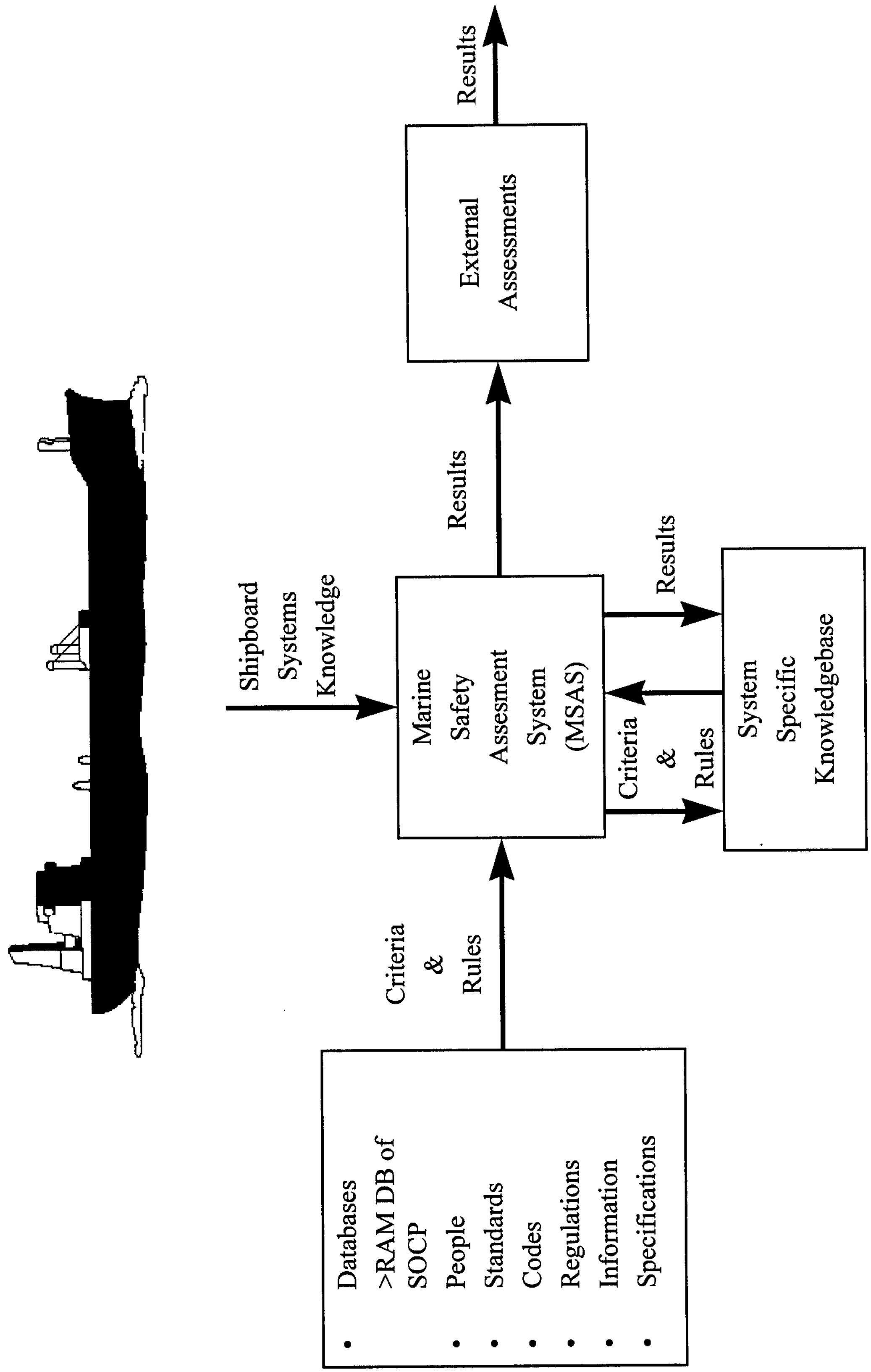


Figure 7 - Marine Safety Assessment System Environment

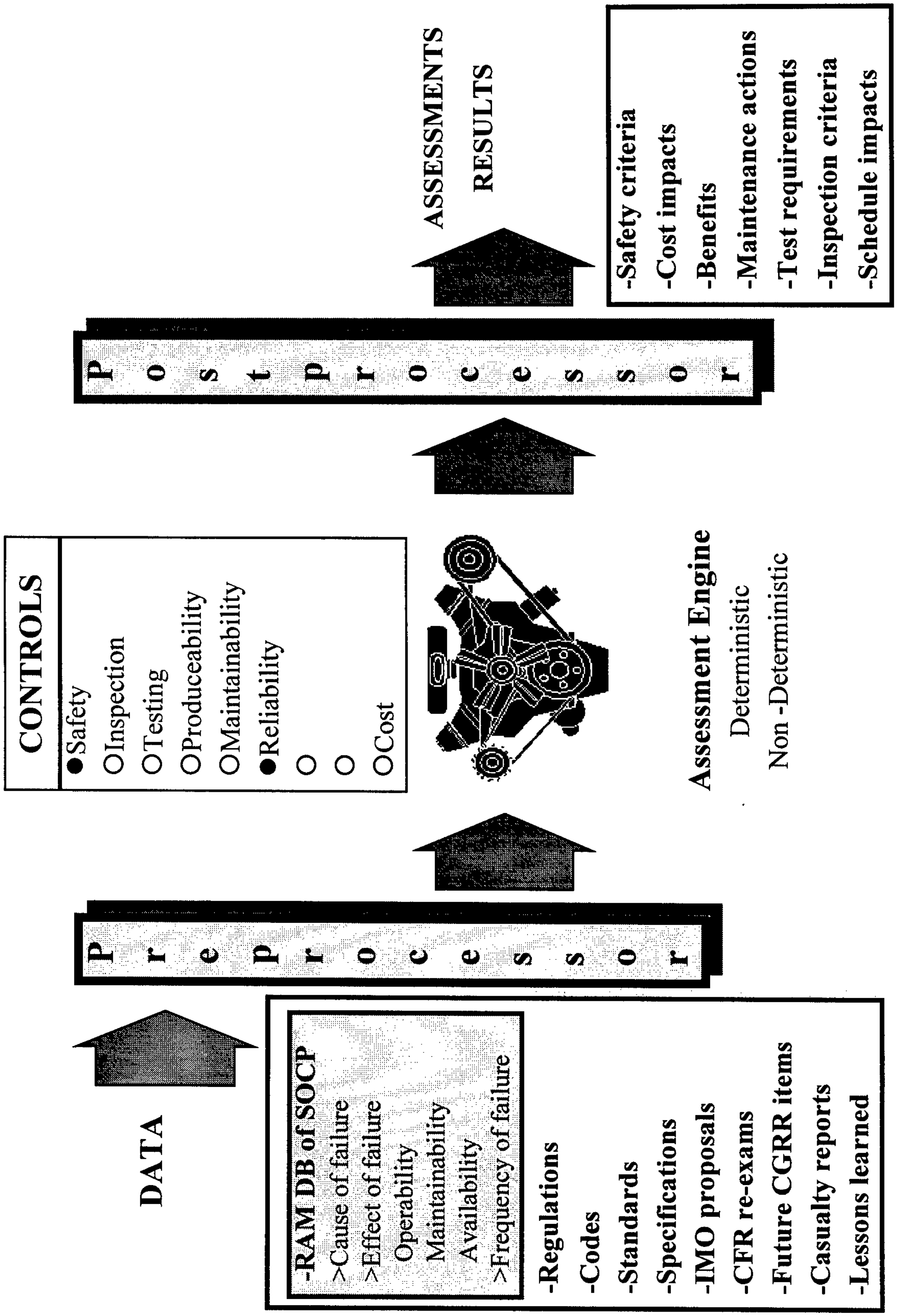


Figure 8 - Functional Relation between RAM Database of SOCP and MSAS

7. FREQUENTLY ASKED QUESTIONS

The following section deals with common inquiries involving data acquisition, program implementation and database operation.

7.1. Implementation Plan

DATE and SHIPPER (beta version 2.0) are now complete and scheduled for at least a three month test ensuring they meet the needs of all participants. Full scale onboard testing of version 2.0 began onboard the LNG VIRGO of ETG and similar testing is planned for other participants. In order to meet company specific needs, it is critical that each company comprehensively tests the software so that it can be fine-tuned to work effectively in all heterogeneous environments.

The implementation plan includes two directions: to begin collecting data *forwards* from the DATE installation date, and to capture relevant historical data from fragmented records *backwards* for target equipment. The collection of data forward will facilitate the continuous improvement objectives of SHIPNET while the retrieval of data from existing records will expedite the improvement of the ship operation process. The collection of historical data will also accelerate the database population growth. This is important because as the database grows, the statistical accuracy will increase and more information will be available for comparison and for advanced uses of data such as spare parts optimization.

The database will also be used by the USCG and ABS for the evaluation of regulations and their potential revision. An interface plan for MSTEP and RAM database is developed and approved for implementation. A detailed implementation plan will be developed during strategic planning in 1996.

7.2. Quality Assurance of Data

The main objective of quality assurance is to ensure the accuracy of data. Data quality must not be sacrificed for the sake of data quantity. The following seven data collection and data analysis "cornerstones" have been identified for the initial quality assurance program of the RAM database: (4)

1. Specification of data requirements
2. Planning of the data collection approach (sequence of systems/ship types, selection of systems, evaluation of data sources, collection procedure, time schedule, etc.)
3. Promoting a common interpretation and understanding among the data collection teams, including exchange of experience during the data collection process.
4. Developing efficient tools and procedures for data collection
5. Preparing a quality assurance plan for the data collection exercise
6. Verification of data quality before, during and after the data collection

7. Reporting of, and acting on, deviations in data quality.

The keys to the success of the SOCP's RAM database are the ship operators and the chief engineers. The chief engineers will play a vital role in data collection with their experience and expertise. Since the chief engineers will be responsible for entering the RAM data, the accuracy of the data will depend heavily on the chief engineers' fulfillment of this responsibility. Hence, it is extremely important that the chief engineers are well informed about the benefits of data collection for the management of continuous improvement in performance, quality and safety and are comfortable with the definitions.

In many cases, chief engineers believe that they are overloaded with numerous responsibilities. Hence, one of the first objectives of the project was to develop a user friendly program for data entry with minimal effort required on the part of the chief engineers. The goal was to achieve standard data entry for a specific maintenance activity in less than three minutes. With most of the data entry from the pop-up menus, this goal has been achieved with the current version 2.0 of the DATE program.

It is mainly the responsibility of the shipping companies to verify the data entries before forwarding them to the master RAM database at GCRMTC. The corrective maintenance and preventive maintenance data fields in DATE are designed to be easily modifiable to make any necessary corrections. Guidance will be provided to facilitate an effective data verification process. Based on Beta testing results of SPIN Version 1.0, additional data verification features will be added to SPIN to automate the verification process as much as possible. If a correction is made in the files that have already been forwarded to the master database, a deviation message describing the change should be sent by the participating company to GCRMTC along with the modified files. A quality assurance plan will be developed as part of the strategic planning task for 1996.

7.3. Automation of Data Entry

We recognize the need for the collection of complete engineering background data related to failures, maintenance and operation. The desired background data includes environmental conditions, vibration levels, the number of times that equipment has been started/stopped, and the exact running hours. This additional data allows a high level of confidence in the failure characteristics developed. The current data fields of the DATE program have been selected by SOCP and include memo fields for the recording of engineering background data. Guidelines will be developed for the chief engineers to collect as much engineering data as is practical using the memo fields. We are planning to attach meters to selected equipment to capture exact running hours. Automating the collection of engineering background data is planned for the second generation of the data collection program.

In the long term, SOCP also plans to automate some of the current data entries of the DATE program. For this purpose, a request for proposals was issued by GCRMTC for the development of the second generation data collection module for the DATE program. This interface application module is to run under the Integrated Shipboard Information Technology (ISIT) platform

currently sponsored by the MARITECH program. The existing data collection mechanism is manual and requires judgment calls by the chief engineers for some critical data fields such as failure type, primary failure causes, and failure criticality levels. Judgment calls have the potential to create inaccurate and/or incomplete data. A significant enhancement to the data collection process would be to furnish actual measurements from shipboard systems automatically providing hard "evidence" data to support and guide the conclusions of the chief engineers, management, regulatory agencies and equipment manufacturers.

Automated collection of supporting "hard evidence" data would be generated directly from shipboard systems, without any manual intervention. This would eliminate potential data entry errors, but far more importantly, would allow the owners/operators to gather data with minimal impact on the workload of their crews while eliminating most of the need for judgment calls and expert opinions. As a result, performance of protective features, root causes of failures, manufacturing defects and near misses can also be easily traced. Consequently, regulatory agencies will also have an enhanced ability to measure the performance of safety standards and regulations and easily evaluate published standards. In addition, ship machinery manufacturers will have a better capability to identify problems associated with the design and recommended operation and maintenance procedures of their equipment.

Some of the fields of the Data Entry Program DATE already reside in various maintenance management computer systems (see Table 2). Currently, individual interface modules are being developed to import data to DATE from various programs to avoid duplication of data entry. The ISIT MARITECH project is expected to develop a standard database structure to store reliability data to reside on an ISIT type client-server database providing interface capability for automated data flow so that the development of costly, company specific, individual modules can be avoided. This project is expected to provide an Application Programming Interface (API) so that any installed maintenance system could update the reliability record. This project will make participation in the RAM program more convenient for owners/operators, which should encourage greater participation in the RAM project. However, the input of the chief engineer will remain an important part of the data collection effort for the foreseeable future, since for some fields, such as repair man hours, data entry cannot be easily and cost effectively automated.

8. CONCLUSIONS AND RECOMMENDATIONS

The RAM database / SHIPNET project is now moving forward into its implementation stage. We already have some demonstrated successes where RAM database / SHIPNET is being used to improve the total life cycle cost efficiency of ships. New decision support tools are being developed to help ship owners/operators make sound vessel management decisions which are consistent with safety and the required reliability. These tools have been developed by the SOCP team through the pooling of expertise, where it is appropriate, and the sharing of R&D costs in a cooperative effort to gain a competitive advantage.

At this stage DATE and SHIPPER have proven to be very functional although certain modifications may be implemented to accommodate each company's specific needs. Chief engineers' overall impression of DATE and SHIPPER have been both constructive and very positive. The SOCP RAM database project is seen as a significant improvement for failure data collection and reliability analysis in the U.S. merchant marine industry.

With the current structure, the immediate beneficiaries of the SOCP's RAM database / SHIPNET will be ship operators and regulatory agencies. Participation of ship designers, shipyards and marine equipment manufacturers is needed and is currently being solicited in order to close the operational experience feedback loop. Significant improvements of new designs, installation parameters, equipment maintenance practices, instruction manuals, personnel training, on board parts stocking, and test equipment will then result from the analysis of data contained in the SHIPS' RAM database. Trends can be established and analyzed to improve corrective maintenance actions, preventive maintenance schedules, and spare parts optimization.

Cultural and legal barriers for data sharing seem to be cracking. If the will of the shipping and shipbuilding communities persists, networking for SHIPS' RAM information sharing will soon become a reality both domestically and globally. The SOCP continues its efforts to accelerate the establishment of an International Ship Network for RAM information exchange. Development of the STEP Life Cycle Change Process Standards for Ships is the first step for meaningful data exchange.

Up to now, the project was devoted to the development of structure and tools for RAM data collection. We have now reached a major milestone: the beginning of implementation. As the implementation stage begins, the project's continued success will depend mainly on the SOCP's ship operating members willingness to collect, transfer, and share accurate ship's RAM data.

Following is a list of where efforts should now be focused:

- Priority needs to be given to <u>onboard</u> as well as shoreside testing of the SHIPNET software.
- Using the feedback from chief engineers, data entry guidelines must be refined to unify the understanding of definitions.

- Strategic planning must be carried out and revised/updated on an ongoing basis.
- If regulatory agencies desire to broaden the scope of data collection, additional incentives should be provided for ship operators in return for supporting the wider data collection scope.
- Efforts to increase SOCP membership and participation in the RAM database project should continue in order to increase the data sample size and accuracy. Publicity about the SOCP and its RAM database/SHIPNET should be increased to accomplish this goal.
- Despite its complexities, international networking should be pursued diligently to ensure the continuous success of the project.
- SOCP members should follow the proper venue through active participation in ASTM to ensure that the needs of RAM database/SHIPNET are addressed in ISO STEP related developments.

The benefits of working together and sharing SHIPS' RAM data are already evident: safer and more reliable ships, higher productivity, greater life-cycle cost effectiveness, and emulation of industry's best practices.

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APPENDIX A
DESCRIPTION OF DATE VERSION 2.0 BETA

A.1. Introduction

DATE software is dedicated to data collection for recording and reviewing machinery operation and failure history. DATE includes five sub-windows :

1. Voyage information window: to collect required information about voyage dates, destination and operation mode.
2. Preventive Maintenance window: to fill out a preventive maintenance activity report, such as major overhauls and equipment replacements.
3. Corrective Maintenance window: to fill out a corrective maintenance activity report, such as repairs due to machinery break-down, degraded performance state, or incipient failure.
4. Equipment data window: to enter equipment information such as placed in service date, manufacturer, serial number, equipment type and operation rates.
5. Equipment class windows: to group pieces of equipment by class.

The program opens to the **start-up screen**. This screen provides an icon for each sub-window (see Figure 9). All sub-windows consist of a selection window that allows the user to choose among different options and a main window that collects/contains the data.

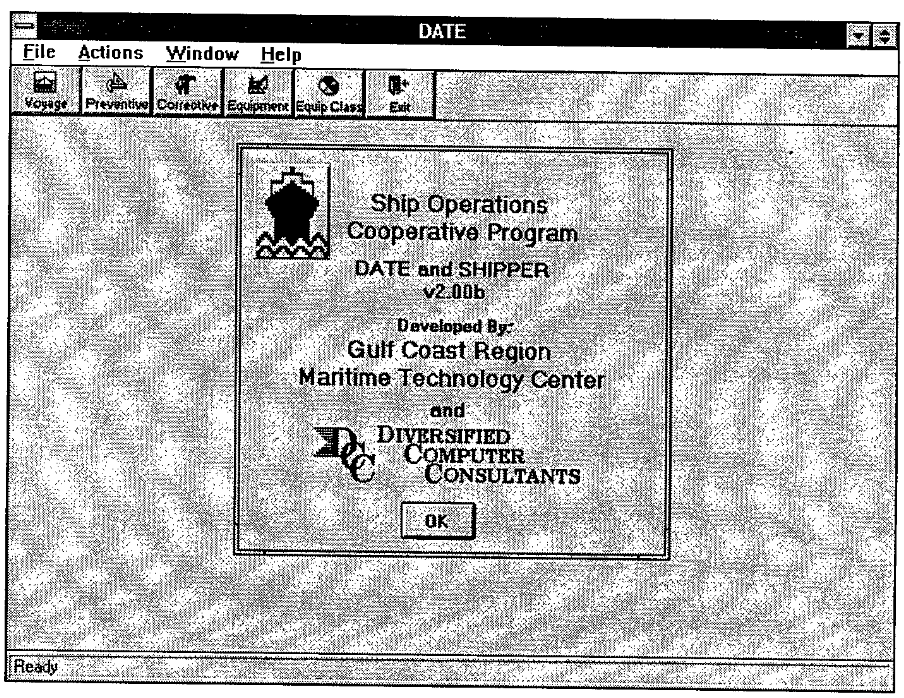

Figure 9 . Start-up window

A.2. Voyage Information

A.2.1. Definitions

1. Voyage: Sailing from point to point or a succession of several points in sequence. The start and end points for each voyage have to be set by the individual company responsible for that ship. Each voyage will be assigned a unique voyage number by the operating company. A voyage will consist of one or more voyage legs.

2. Voyage leg: A voyage leg is a subset of a voyage consisting of the movement of a vessel from one point to another with a corresponding change in vessel operating mode - in port/anchor to at sea (steaming) to in port/anchor. The company controlling the voyage of the ship will determine the beginning and end of a voyage leg.

3. Operation at Sea (Steaming) Mode: Ship is underway. From Standby Engines to Finished With Engines or from Last Line to First Line.

4. Operation in Port: Ship is in "all fast" condition. Ships are in port for either loading or unloading. Cargo loading equipment, power generation systems and a few auxiliary systems operate during this mode.

5. Operation at Anchor: The "At Anchor" operation mode begins at "finished with engines at anchor." This mode of operation may or may not have the same auxiliary equipment operating as the vessel "Operation in Port" mode.

If a vessel normally conducts cargo operations while at anchor (i.e. Single point mooring for oil tankers), the Chief Engineer may consider setting the Equipment Run-time Percentage for "Operation in Port" to apply to the conduct of cargo operations while at anchor. In this case, the "Operation at Anchor" mode would only be selected when the vessel is at anchor awaiting a berth or safe passage but not conducting cargo operations.

6. Shipyard (Dry-dock) / Lay-by: Essentially all equipment is shutdown and only a few auxiliary items may be operating. The chief engineer is responsible for overriding the cumulative running hours of equipment which remain operational during the dry-dock / lay-by period.

A.2.2. Selection Window

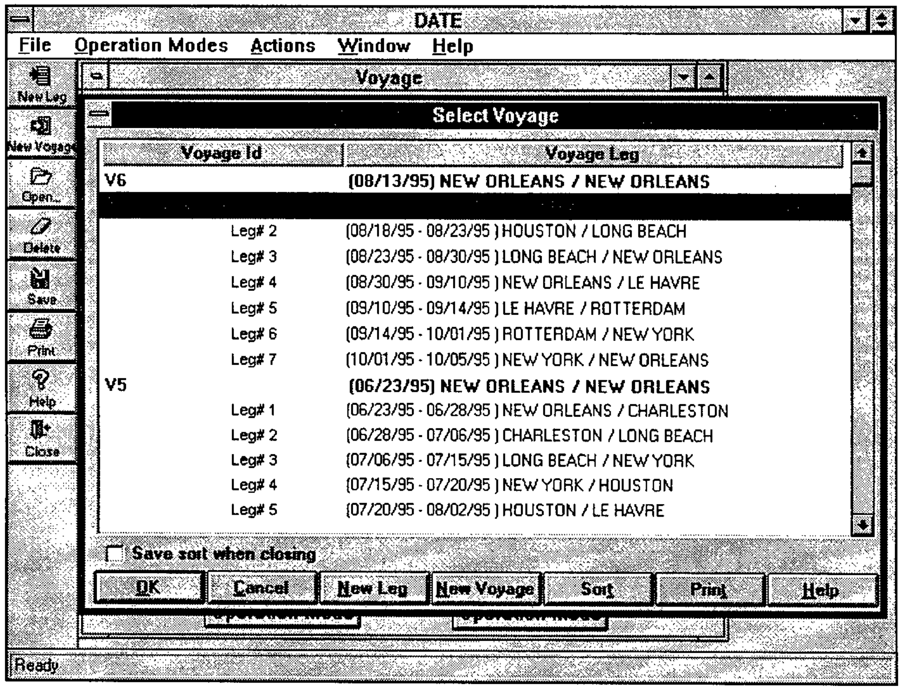

Figure 10 . DATE Voyage Selection Window

The **voyage selection window** (see Figure 10) includes the following options:

1. Choose the OK button to display, modify or delete an existing voyage leg, which can be selected using the scroll bar.
2. Choose the CANCEL button to go back to the main window.
3. Choose the NEW LEG button to add a new leg to an existing voyage.
4. Choose the NEW VOYAGE button to create a new voyage.
5. Choose the SORT button to modify the selection window sorting option.
6. Choose the PRINT button to print the list of voyages
7. Choose the HELP button to access the on-line help. The on-line help can be accessed from any of the DATE windows.

A.2.3. Main window

The user can display existing leg information by selecting the leg and clicking OK at the **selection window** (see Figure 10). Each voyage must be identified by a number or any kind of ID. DATE automatically assigns a number to each leg. The user must enter the start port, the end port, the start date and time of the leg, the end date and time of the leg.

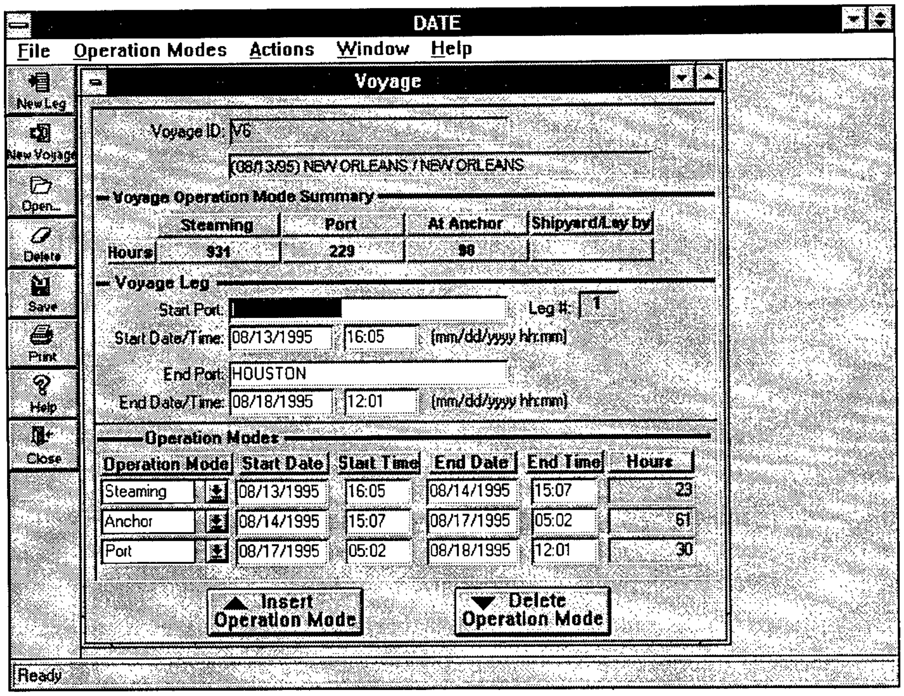

Figure 11 . DATE Voyage Information Window

For any DATE window, the user can go to the next field by using the mouse or pressing TAB (shift TAB to go to the previous field).

DATE assumes that the ship can operate under four different voyage operation modes: steaming, in port, at anchor and at the shipyard/lay-by. The voyage operation mode summary provides the user with the number of hours that the ship spent under each operation mode during the complete voyage. The user must enter operation mode start and end dates for each leg. By default, DATE assumes that a voyage is composed of a steaming period and a port stay, which is the most common case. The leg start date is automatically duplicated as the steaming period start date and the leg end date is duplicated as the port period end date. The user can add another operation mode by clicking on the "insert operation mode" button. The mode type is selected using the drop-down menu. Leg operation mode hours are automatically computed.

Similar to every DATE window, the entered information must be saved before exiting. DATE will remind the user if entries or changes are not saved when the user exits. The data can be saved by either clicking on the save button or by selecting "save" on the file option of the menu bar. DATE checks for data inconsistency and warns the user if necessary.

The user can go back to the **selection window** (Figure 10) by clicking on the OPEN button on the left side of the screen. A new leg or a new voyage can be entered by clicking on the NEW LEG or NEW VOYAGE button. These actions can also be performed using the file option of the menu bar. Every DATE window is equipped with a

print preview, which can be accessed either by clicking on the PRINT button or by selecting PRINT on the file option of the menu bar. The print preview allows the user to display each page successively before printing a report (see Figure 12).

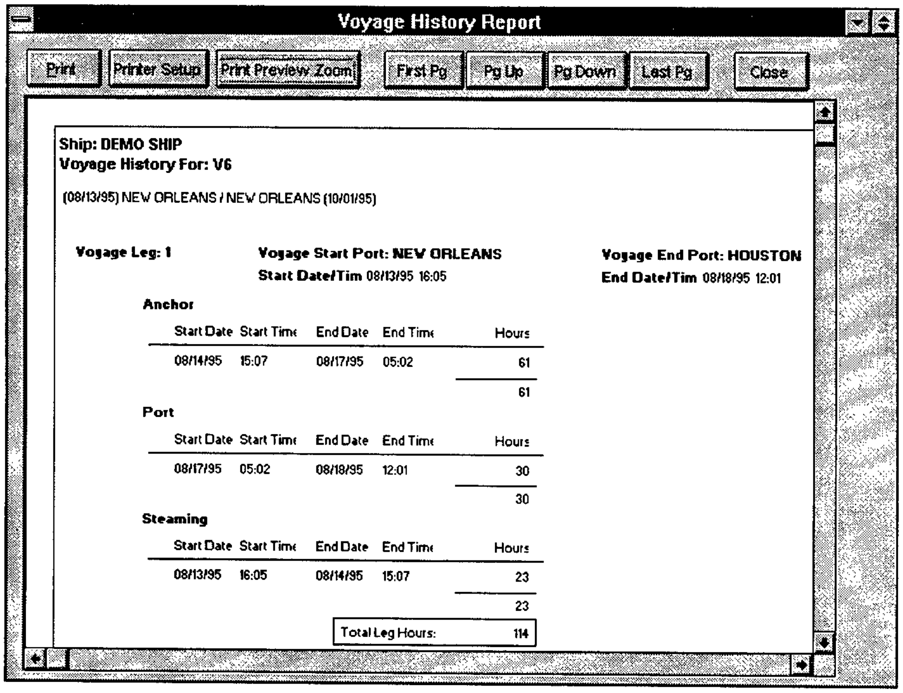

Figure 12 . DATE Voyage Information Print-Preview

A.3. Preventive Maintenance Sub-Window

A.3.1. Definitions

1. Preventive (Scheduled) Maintenance: Periodic prescribed inspection and/or servicing of equipment accomplished on a calendar, mileage or hours of operation basis. Preventive Maintenance comprises all scheduled maintenance actions performed in an attempt to retain a system/piece of equipment in a specified condition and prevent its failure, including the accomplishment of periodic inspections, condition monitoring, component replacement due to normal expected wear and tear, routine maintenance (servicing), and calibration.

2. (Preventive Maintenance) Action Date: The date that the preventive maintenance action has been completed for the piece of equipment.

3. Cumulative Running Hours: the total number of hours that the equipment has been running since it was installed on that vessel. The cumulative running hours is set to zero when the equipment is installed and the hours keep accumulating until it is replaced with a new piece of equipment.

4. Running Hours: Running hours are the number of hours that the equipment has been in service running since it was either placed in service or since the last complete overhaul which refurbished the equipment to a condition as close as practical to the original manufacturer's specifications. Running Hours starts at zero when the equipment is installed and is always reset to zero whenever the equipment is given a complete overhaul or replaced. The program calculates Running Hours by subtracting the Cumulative Running Hour figure at the last Complete Overhaul from the Cumulative Running Hour figure at the current maintenance event. The Running Hours display in the program will be updated when the Chief Engineer over-writes the Cumulative Running Hours figure.

5. Complete Overhaul: An action, or series of actions, taken when an item is completely disassembled, refurbished, reworked, tested, and returned to a condition meeting all requirements set forth in applicable specifications. All components are returned to a "like new" condition and running hours for the equipment will be reset to zero. "Like New" is defined as placing all components designed to wear out in a condition as close as practical to the original manufacturer's specifications. A complete overhaul is a preventive maintenance action and can be performed in conjunction with a corrective maintenance activity.

6. Partial Overhaul: An action or series of actions taken when an item is partially disassembled refurbished, reworked, tested, and returned to a condition which meets some but not all applicable specifications. Some, but not all, components are returned to a " like new" condition. The running hours for the equipment will not be reset to zero. A partial overhaul is a preventive maintenance action and can be performed in conjunction with a corrective maintenance activity. For example, disassembling a pump and replacing the seals and a set of bearings, while not replacing the thrust bushing(s) and casing wearing rings, which are found to be worn greater than the pump manufacturer's specified tolerance, constitutes a partial overhaul.

7. (Preventive Maintenance) Replacement (same model): Replacing a piece of equipment with the same model to enhance efficiency/safety or to reduce frequency/cost of corrective action. This action requires entry of a new serial number in the equipment database of DATE.

8. (Preventive Maintenance) Replacement (different model): Replacing a piece of equipment with a different model to enhance efficiency/safety, to reduce frequency/cost of required corrective action, or due to obsolescence of the original equipment. This action requires entry of a new model, serial number and the rest of the nameplate data in the equipment database of DATE.

9. Routine Service / Inspection: Routine service/inspection is the act of performing inspection and/or minor maintenance on a piece of equipment at a defined frequency for the purpose of preventing its failure. This includes the task of changing oil, lubricating,

cleaning or changing filters, renewing zincs, painting or adjustments to arrest wear, corrosion, etc., or to prevent its premature occurrence. Examples include:

- changing oil
- lubricating
- changing filters
- applying protective coatings

A.3.2. Selection Window

Like the voyage information sub-window, the preventive maintenance sub-window includes both a selection window and a main window. The **selection window** allows a user to select a previously entered repair activity or to begin a new preventive maintenance activity. The **main window** allows the user to view or modify the existing activity or to enter the maintenance detail for the new activity.

Similar to the voyage selection window, existing report can be displayed and new entries can be made from the preventive maintenance selection window (see Figure 13).

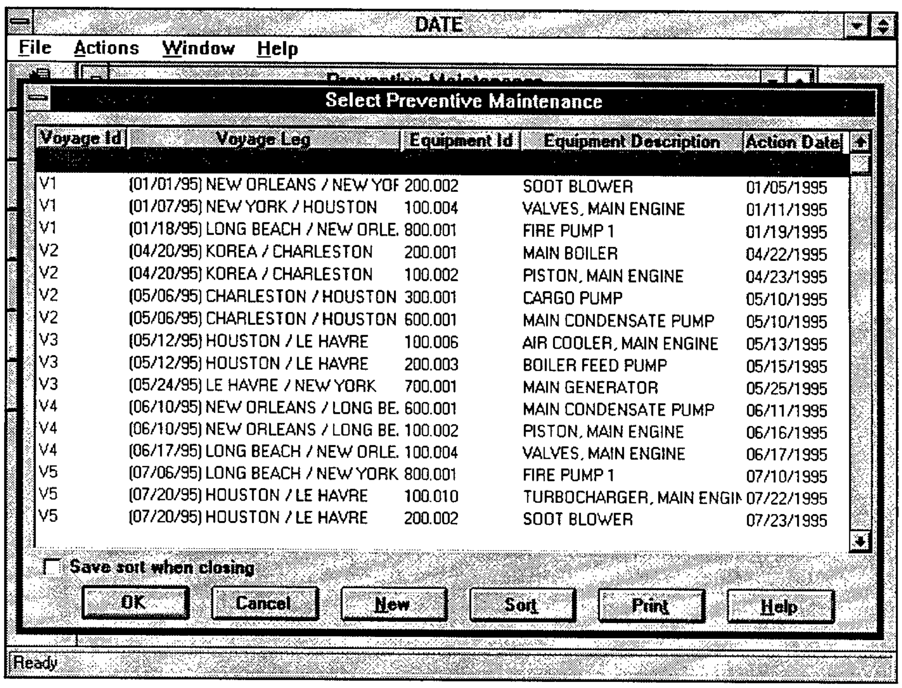

Figure 13 . DATE Preventive Maintenance Selection Window

The preventive maintenance selection window includes the following options:

1. choose OK to display, modify or delete an existing entry.
2. choose CANCEL to go back to the main window.
3. choose NEW to enter a new preventive maintenance activity report.

4. choose SORT to modify the sorting option of the preventive maintenance selection window.
5. choose PRINT to print the list of preventive maintenance activities
6. choose HELP to access the on-line help.

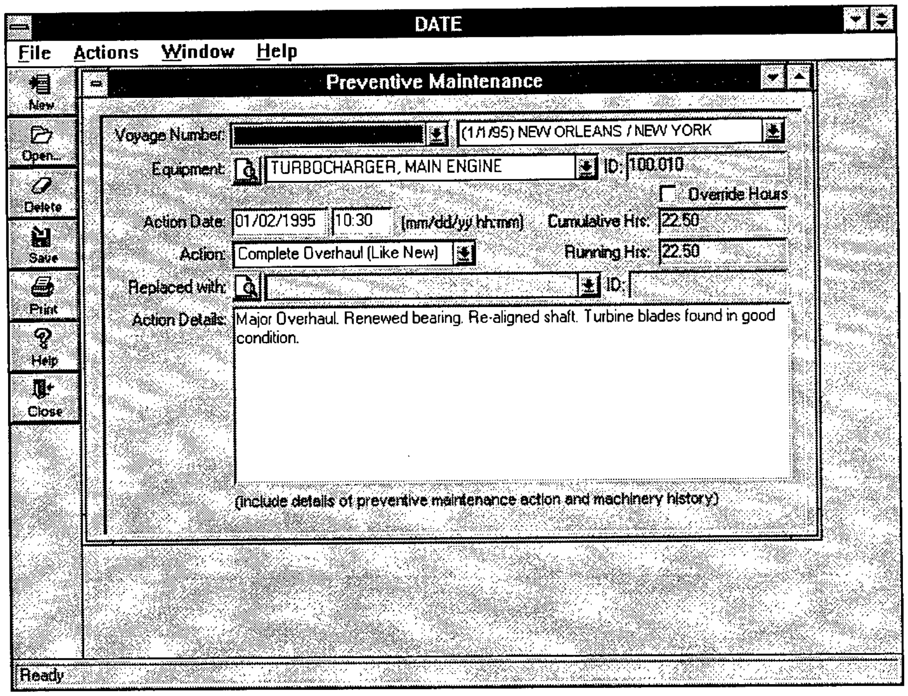

Figure 14 . DATE Preventive Maintenance Report Window

A.3.3. Main Window

At the selection window, an existing report can be displayed by selecting the report with the mouse or arrow keys and clicking OK (see Figure 14).

For a new activity, the user must click the “NEW” button on the selection window, then select the voyage number and leg that correspond to the activity from the pop-up menu. The piece of equipment for which an entry is made can be selected from the equipment list by clicking on the icon that shows a magnifier. This opens the equipment list and provides the user with search capabilities (see Figure 15).

The list can be searched by equipment name or equipment ID. The search is initiated by entering either an equipment name or an equipment ID and clicking on the RETRIEVE button. The equipment is selected by highlighting it with a mouse click or arrow keys and then clicking on the OK button, or double clicking on the highlighted line.

The activity date and time must then be entered. Based on this information, Cumulative Running Hours (CRH) and Running Hours (RH) are automatically calculated using the equipment operating rates. The user can choose to override CRH in order to correct the

estimation that is based on equipment operating rates. The "override hours" box has to be checked before any value can be entered (see Figure 16).

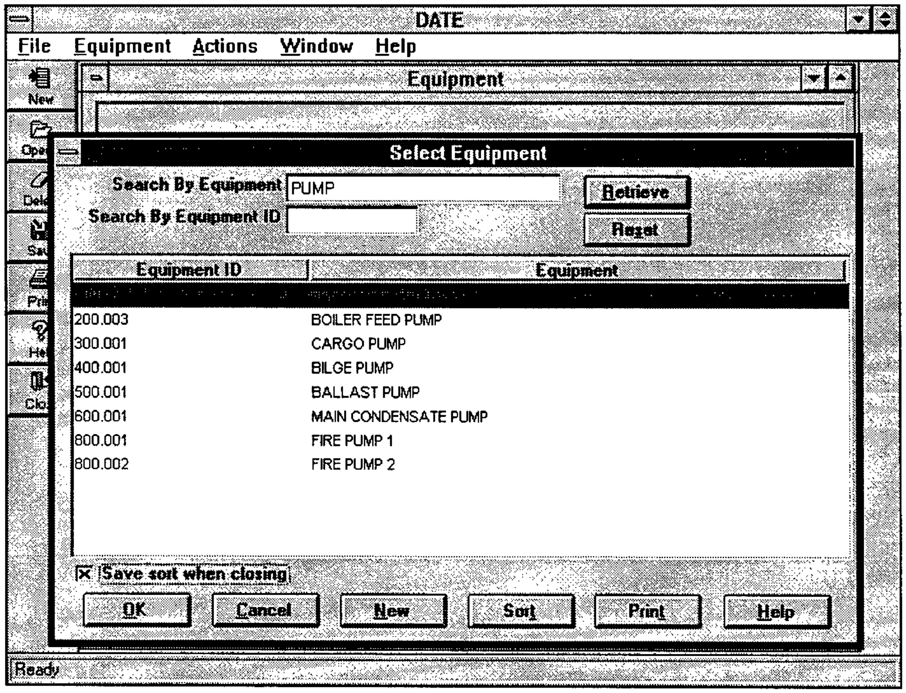

Figure 15 . DATE Equipment Search

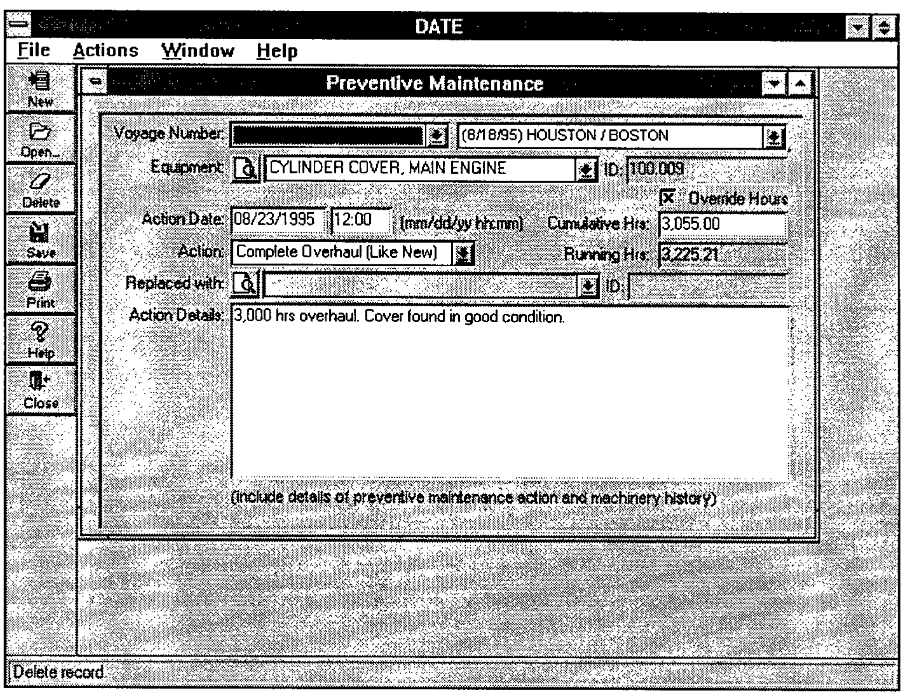

Figure 16 . DATE Cumulative Running Hours Override

DATE identifies six special types of preventive maintenance activities (see Figure 17):

- complete overhaul (like new)
- replace with the same model
- replace with a different model
- routine service / inspection
- partial overhaul
- other

If the piece of equipment is replaced with a different model, the name and ID of the new piece of equipment must also be entered.

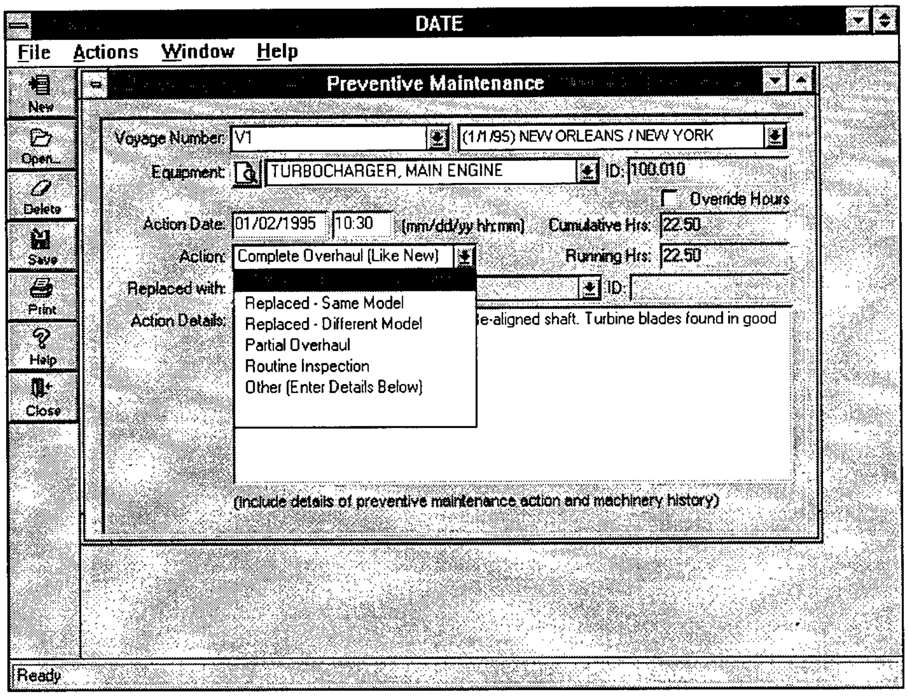

Figure 17 . DATE Preventive Maintenance Action Types

A brief description of the job can be entered in the detail section.

Similar to the voyage information window, the user can use either the buttons on the left side of the screen or the menu bar to enter a new activity, to open the selection window, to delete an existing activity, to save new entries, to access the print preview or to exit the application.

A.4. Corrective Maintenance Window

A.4.1. Definitions

1. Corrective (Unscheduled) Maintenance - Breakdown: All unscheduled maintenance actions performed as a result of system/equipment failure, to restore the system to a

specified condition. Corrective Maintenance includes failure identification, localization/isolation, disassembly, item removal and repair or replacement, re-assembly, test and condition verification. Corrective Maintenance may occur as a result of a suspected failure (incipient failure, see definition below), even if further investigation indicates that no actual failure occurred.

2. Activity Start Date and Time: For the first activity, this will be when the failure occurred or was first noticed. When the temporary repair option is chosen, for subsequent repair events, "Activity Start" is defined as the beginning of the subsequent repair activity. For example, for the second temporary repair following a failure, the "Activity Start" entry will be the date/time of the start of the second temporary repair activity.

3. Activity End Date and Time: For a permanent repair, the "Activity End" entry will be the date/time that the permanent repair was completed.

If a temporary repair option is chosen, the "Activity End" entry will be the date/time:

- at the end of the Logistics Delay period when option 1 has been chosen - Equipment Unrepairable or Inoperable

- when the Temporary Repair is completed and the equipment is placed back in limited or full service if options 2 or 3 are chosen (Option 2 - Temporary Repair Made with Degraded Performance Option 3 - Temporary Repair Made with No Reduction in Performance)

4. Permanent Repair: All required corrective maintenance has been completed on the failed component and/or piece of equipment returning it to a condition suitable for continued reliable service. The person performing the repair feels that no additional repair or preventive maintenance action on that component and/or piece of equipment is required until the next scheduled maintenance action.

If, in conjunction with the repair, a Complete Overhaul (Preventive Maintenance Action) of the piece of equipment is carried out then this constitutes a Permanent Repair with Complete Overhaul of Equipment. The corrective maintenance action should be entered in the corrective maintenance window of DATE and the corresponding Preventive Maintenance entry will be automatically entered by the program. (See definition of Compete Overhaul.)

Permanent Repair Options - (All temporary repair folders are closed with this entry). As detailed in section A.4.4., the following options will replace the current "permanent repair" option:

- Option 1 - **Permanent repair with no reduction in performance**: The defective component was replaced or repaired and the equipment was returned to good operating condition.

- Option 2 - **Permanent Repair with Complete Overhaul of Equipment**: Based on a practical decision to improve logistics efficiency, in addition to replacing or repairing the defective component, the next scheduled preventive maintenance overhaul was moved forward and the equipment was completely overhauled and returned to a "like new" condition. When option 2 is chosen the computer program will enter the preventive maintenance action automatically.
- Option 3 - **Equipment Replaced - Same Model**: Corrective maintenance carried out by replacing equipment with a new unit of the Same Model. (Prompts user entry of New Serial Number)
- Option 4 - **Equipment Replaced Different Model**: Corrective maintenance carried out by replacing equipment with a new unit of the Different Model. (Prompts user entry of New Nameplate Data and Serial Number)

5. Temporary Repair: All required corrective maintenance has not been completed on the failed component and/or piece of equipment. The person performing the repair feels that additional repair action on that component and/or piece of equipment is required to return the equipment to a condition suitable for continued reliable service.

For each Corrective Maintenance Action entry noting a Temporary Repair, a repair folder is open in the Corrective Maintenance Action database. This folder remains open in the database until a permanent repair is completed on the piece of equipment and an entry noting the permanent repair is made by the Chief Engineer.

There are three options to choose from when making a Temporary Repair entry in DATE:

- **Equipment Unrepairable or Inoperable (Awaiting Permanent Repair)** [Temporary Repair Folder Open] The user must enter a Logistics Delay i.e. Delay waiting for Spare Parts, Replacement Equipment (Same or Different Model), Technical Expertise, or More Comprehensive Facilities (Shipyard or Shoreside Repair facilities). Equipment cannot be operated in its present condition. Attempt to repair equipment may or may not have been made.

- **Temporary Repair Made with Degraded Performance** [Temporary Repair Folder Open] - Temporary Repair has been carried out to failed component. Equipment has not been repaired back to the condition that it was in prior to the occurrence of the failure. Failure of component has caused piece of equipment to not meet all operating performance requirements. Repaired equipment is not in a condition to successfully support the completion of vessel's intended mission.

  If there is not a high confidence level that the repair is going to last at least until a Permanent Repair can be made, or reduced confidence in the reliability of the piece of equipment (on a normal operating basis) Option 2 should be chosen.

- **Temporary Repair Made With No Reduction in Performance** [Temporary Repair Folder Open] Temporary Repair has been carried out to failed component. Repaired

equipment is in a condition to successfully support the completion of vessel's intended mission. There is a high level of confidence that the repair will last until a Permanent Repair can be made.

6. Repair Man Hours: number of people who worked on this activity on this piece of equipment times the sum of the number of hours that each of them worked.
Example:
2 persons worked 3 hours each → subtotal Repair Man Hours = 6
4 persons worked 1 hour each → subtotal Repair Man Hours = 4
Total = 10 Man Hours

Repair Man-hours should include all time spent working on the activity including time spent in planning the job, making special tools, and researching/ordering spare parts. Any kind of operation that is essential and required for the repair of that particular piece of equipment should be included in the repair man-hours. The Chief Engineer may enter any details pertaining to the repair man-hours in the memo field if required.

7. Logistics Delay - Non-availability of resources onboard to make the PERMANENT repair:

The logistics delay should be captured for critical equipment if the delay has a potential significant impact on cost or vessel mission.

If the Permanent Repair cannot be completed within a reasonable period from the date of failure, a Temporary Repair entry must be made and all of the Logistics Delay associated with the failure must be captured when making the Permanent Repair entry. The Chief Engineer should take into account the criticality of the equipment for the vessel mission or safety, redundancy of the failed equipment, costs associated with the logistics delay, and length of the repair delay in deciding what constitutes a reasonable period.

8. Complete Failure: A Complete Failure causes the immediate and complete loss of the equipment making it incapable of meeting its intended service. Repairs are required before re-starting the equipment.

- The equipment automatically shuts itself down due to a severe mechanical or electrical problem or an overload condition, or the operator shuts it down and it cannot be restarted until it is repaired.
- The equipment has failed. Its ability to continue running and meet its intended service is zero.
- The equipment is unable to meet the minimum performance requirements of the required service.

9. Degraded Performance: Degraded Performance means the gradual loss of function or sudden degradation of equipment's performance where the equipment is still operable i.e. loss of efficiency. The equipment is still able to function but certain equipment operating characteristics have deteriorated. There may be a reduction in the confidence level of the

continued reliable operation of the equipment. These type reasons for repair may not always lead to immediate repair but are often postponed to some convenient time period.

10. Incipient Failure: A malfunction which does not immediately cause the loss of the equipment's functional capability to meet its intended service or a loss of efficiency. If the malfunction is not attended to in the near future, it may lead to Degraded Performance or a Complete Failure of the equipment.

11. Failure Type: Component that initiated the failure defines the type of failure. If multiple failures have occurred select root cause of the problem.

12. Electrical failure:

- component that initiated failure is electrical in nature.
- component that initiated the failure of a series of components is electrical in nature.
- root cause of the failure was directly related to an electrical problem.

13. Mechanical failure:

- component that initiated failure was mechanical in nature.
- component that initiated the failure of a series of components is mechanical in nature.
- root cause of the failure was directly related to a mechanical problem.

14. Critical Failure: Critical Failure of the equipment prevents the vessel from performing its intended mission or poses a grave safety hazard to the vessel, vessel personnel or the environment.

15. Major Failure: Major Failure of equipment reduces the vessel's capability to perform its intended mission on a sustained basis i.e. reduced efficiency, vessel speed, non-availability of back-up for critical equipment, etc. A major failure does not pose an immediate major safety or environmental hazard but may in the immediate future.

16. Minor Failure: Minor Failure of equipment does not affect the performance of the vessel, is not essential for sustained vessel operation, nor does it pose any safety or environmental hazard. It may be nice to have operational but it is basically not required.

17. Total Mission delay time: the vessel fails to meet its intended schedule due to the failure of a piece of equipment.

A.4.2. Selection Window

Like the voyage information sub-window, the corrective maintenance sub-window includes both a selection window and a main window. The **selection window** allows a user to select a previously entered repair activity or to begin a new corrective maintenance activity. The **main window** allows the user to view or modify the existing activity or to enter the action details for the new activity.

Failure activity reports are based on the concept of folders. Each corrective maintenance activity is kept in a folder. A folder can start with a temporary repair and remain open until a permanent repair is performed. A folder can also contain only one activity if this activity is a permanent repair immediately following a failure. The Corrective Maintenance selection window includes three types of display:

- The default display lists all the repair activities and does not show the folders (see Figure 18).
- The option "temporary repair open folders" displays the repair activities that have not been completed by a permanent repair (see Figure 19).
- The option "all folders" displays all closed and open folders (see Figure 20).

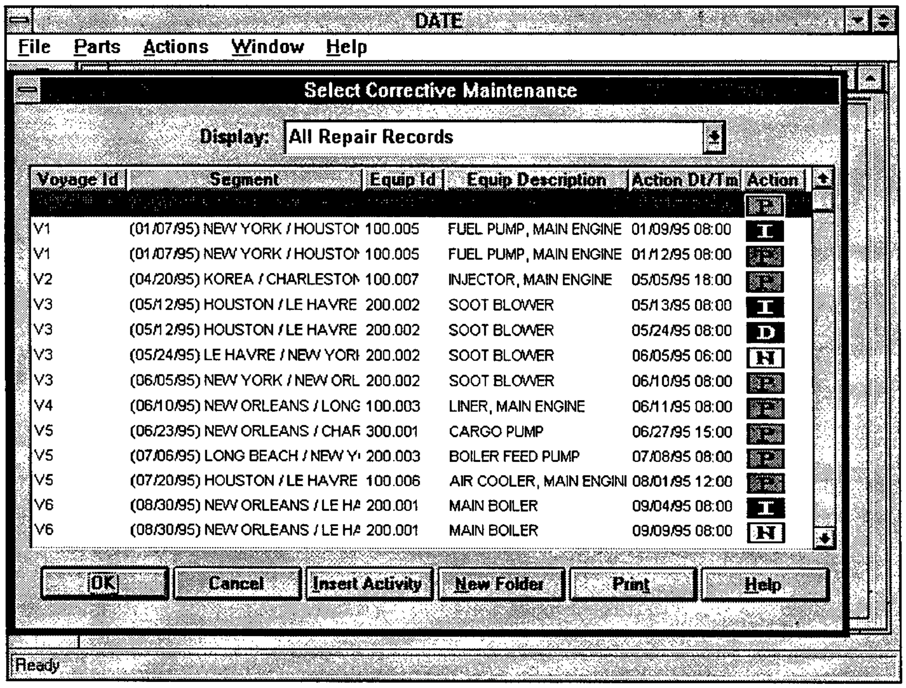

Figure 18 . DATE Corrective Maintenance Selection Window (All Repair Records)

The corrective maintenance selection window includes the following options:

1. choose OK to display, modify or delete an existing entry.
2. choose CANCEL to go back to the main window.
3. choose INSERT ACTIVITY to add a new activity to an existing folder.
4. choose CREATE FOLDER to create a new folder.
5. choose PRINT to print the list of corrective maintenance activities
6. choose HELP to access the on-line help.

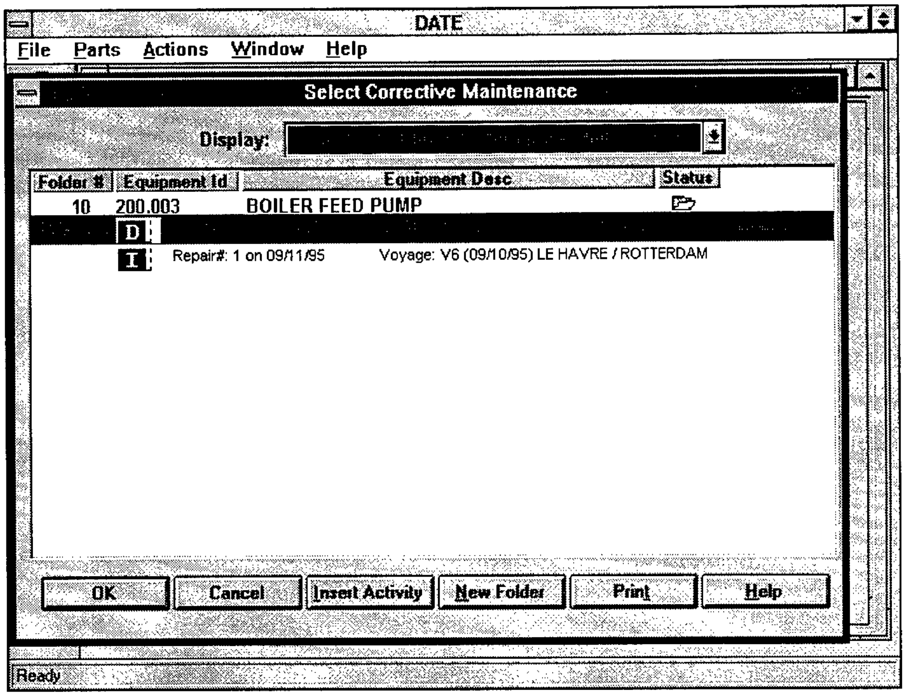

Figure 19 . DATE Corrective Maintenance Selection Window (Temporary Repair Open Folders Only)

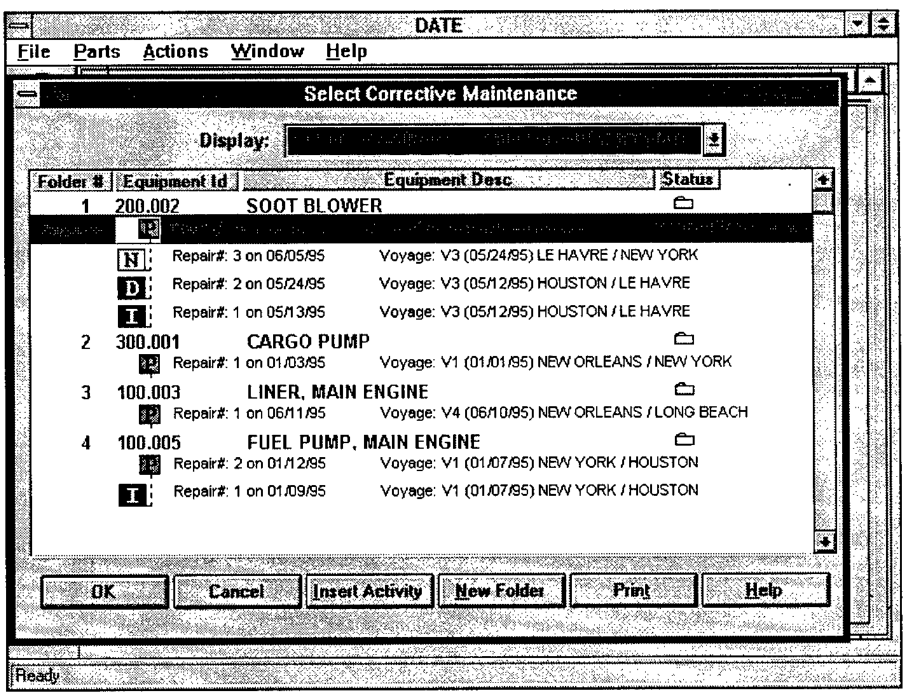

Figure 20 . DATE Corrective Maintenance Selection Window (All Repair Folders Temporary & Permanent)

A.4.3. Main Window

An existing report can be displayed by selecting the report with the mouse or arrow keys and then clicking OK at the selection window (see Figure 21). DATE automatically assigns a number for each folder and for each repair within a folder. The equipment selection is the same as for the preventive maintenance window, with identical searching capabilities. Similar to the Preventive Maintenance report, the user can override Cumulative Running Hours to correct the estimation which is based on equipment operating rates.

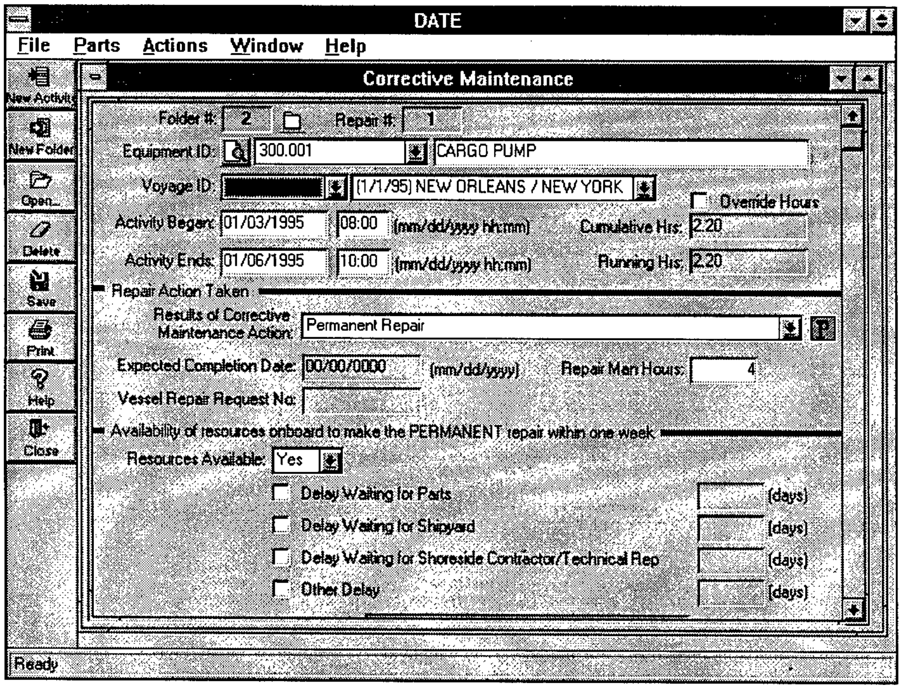

Figure 21 . DATE Corrective Maintenance Report Window

Corrective maintenance repairs are classified under four categories (see Figure 22):

- Permanent repair [green icon : P]
- Temporary repair with NO reduction in performance [yellow icon : N]
- Temporary repair with degraded performance [pink icon : D]
- Equipment unrepairable/inoperable (hold for arrival in port or shipyard) [red icon : I]

The user specifies whether the resources were available or not and enters the reason and the duration of delays, if any. A brief description of the repair can be entered in the detail section. The user specifies the location of the repair, the result of the repair, who performed the repair, the reason for repair and the means by which the failure was discovered. For each of these items, DATE proposes answers that can be accessed using drop-down menus. If the failure was discovered during an inspection, the inspection type drop-down menu becomes active for selection among various proposed inspection types. The user can choose "other" and specify the nature of the inspection. Also, if the failure

discovery does not correspond to any of the proposed items, the user can choose "other" and enter the appropriate answer in the text box. The user has to specify the failure type and the failure cause.

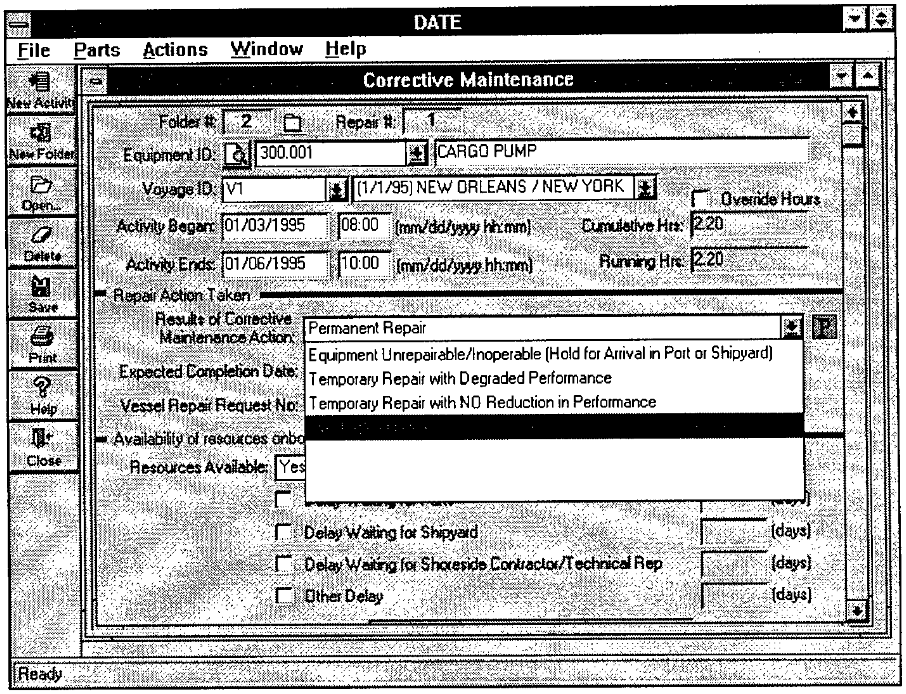

Figure 22 . DATE Corrective Maintenance: Action Types

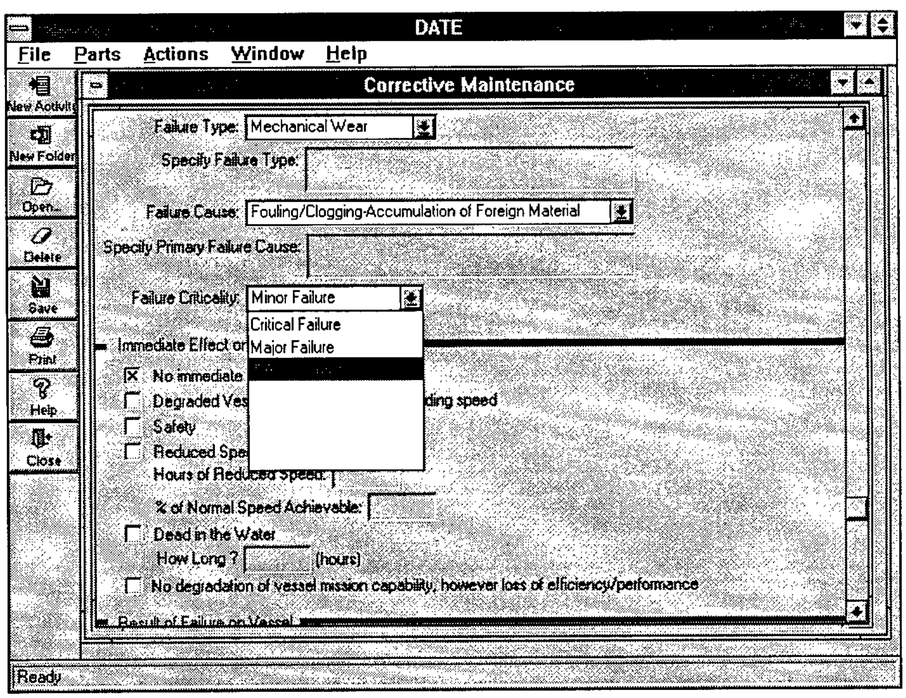

Figure 23 . DATE Corrective Maintenance: Failure Criticality Selection

Failures are classified under three categories, namely critical, major and minor. DATE proposes various options for the effect of the failure on the ship operation. If "reduced speed at sea" is chosen, the fields "hours of reduced speed at sea" and "% of normal speed achievable" have to be filled out. If "dead in the water" is chosen, the duration has to be entered. If the vessel failed to perform its mission, the total mission delay time has to be entered.

The various fields that have to be filled out and the corresponding proposed answers are the following :

Availability of resources onboard to make the PERMANENT repair in less than a week

Resources Available: *(YES/NO) No enables the following:*

☒ Delay Waiting for Parts _____(days) *(opened when checked)*
☒ Delay Waiting for Shipyard _____(days)
☒ Delay Waiting for Shipyard Contractor/Tech. Rep. _____(days)
☒ Other Delay *(enables text box below)* _____(days)
Specify: *Text box*

☒ - *click box* : Total Delay ______(days) *Automatic Tally with Override Capacity*

Memo field #1: Corrective Action Details

Enter detailed description of root cause of failure, temporary repairs made, description of logistics delay time like which part caused the longest delay, special problems encountered, special tools required, any machinery history data , etc. *Text box.*

Location of Permanent Repair Action Taken

Location of Permanent Repair: *Pop-up menu (select one)*
>Shipboard - at Sea
>Shipboard - in Port
>Shipyard
>Equipment Removed from Ship

Permanent Repair Performed By: *Pop-up menu (select one)*
>Ship's Crew
>Contractor's Crew / Shipyard
>Manufacturer's / Technical Representative

Corrective Maintenance (Repair) Activity

Reason for Repair: *Pop-up menu (select one)*
>Complete Failure
>Degraded Performance
>Incipient Failure

Repair Discovered: *Pop-up menu (select one)*
>During Startup of the Equipment
>During Normal Operation
>During Regulatory, Customer or Company Required Inspection *(enables Inspection Type below)*
>During Preventive or Predictive Maintenance - Excluding Inspection
>While Performing Other Repair Work Due to Another Failure
>Other *(enables text box below)*
    Specify: *Text box*

Inspection Type: *Pop-up menu (enabled only for "During Regulatory, Customer or Company Required Inspection" above, select one)*
>ABS
>USCG
>Company Required
>Customer Required
>Public Health
>Other *(enables text box below)*
    Specify Why Inspected: *Text box*

Failure Data

Failure Type: *Pop-up menu (select one)*
>Mechanical Wear
>Mechanical Fracture
>Electrical
>Other *(enables text box below)*
    Specify Failure Type: *Text box*

Failure Cause: *Pop-up menu (select one)*
>Communications Problem
>Inadequate Design
>Corrosion Deterioration
>Fouling/Clogging - Accumulation of Foreign Material
>Normal Wear and Tear
>Inadequate Lubrication
>Loosening of Component Fasteners
>Other *(enables text box below)*
    Specify Primary Failure Cause: *Text box*

Failure Criticality: *Pop-up menu (select one)*
>Critical Failure
>Major Failure
>Minor Failure

Immediate Effect on Ship's Operations

☒ No immediate effect on Ship's Operations
☒ Degraded Vessel Mission Capability Excluding Speed
☒ Safety
☒ Reduced Speed at Sea
Hours of reduced Speed: _____ % of Normal Speed Achievable: _______
☒ Dead in the Water
How Long? _______ (hours)
☒ No degradation of vessel mission capability, however loss efficiency/performance

☒ - *click box*

Result of Failure on Vessel

Vessel Failed to Perform Intended Mission: *Pop-up menu (yes or no)*
Total Mission Delay Time:________(hours)

Memo field #2: Enter details of failure criticality, effect on vessel performance, safety ramification, associated with the corrective maintenance action: *Text box*

Parts Information

Part #, Quantity, Cost Per Unit as a list

Part#	Quantity	Cost per Unit	Total *(AUTOMATIC)*

Parts information is located in a separate window, which can be accessed by clicking on the "PARTS" button (see Figure 24). This opens a new window where part number, part cost and quantity can be entered by clicking on the "INSERT" button or deleted by clicking on the "DELETE" button. Total cost for each repair and cumulative cost for the complete folder are automatically computed. The user goes back to the corrective maintenance main window by clicking on the "OK" button.

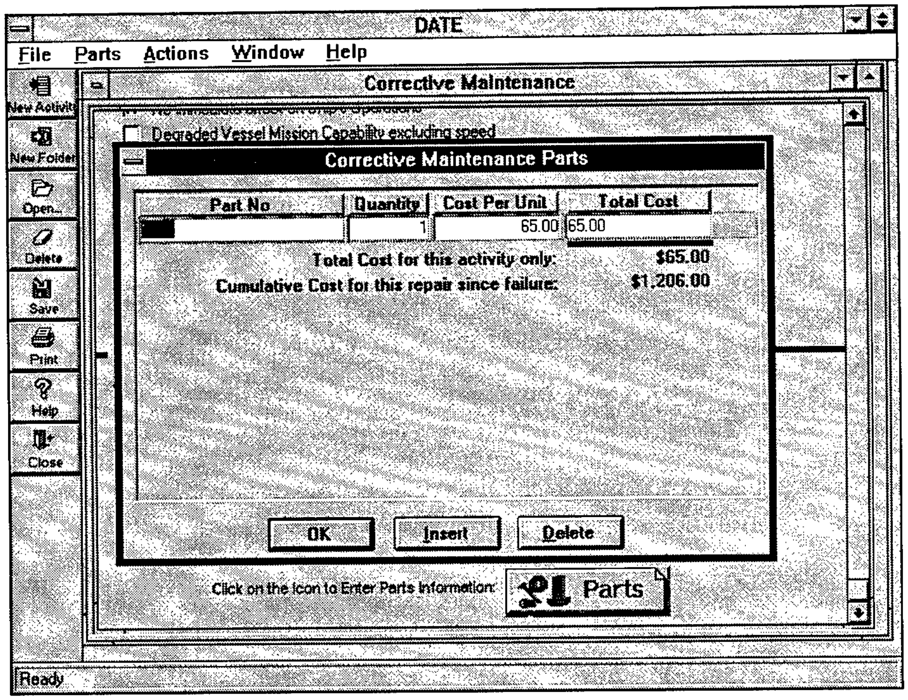

Figure 24 . DATE Corrective Maintenance Part Window

From the Corrective Maintenance main window, the user can use either the buttons on the left side of the screen or the menu bar to enter a new activity, to create a new folder, to open the selection window, to delete an existing activity, to save new entries, to access the print preview or to exit the application.

A.4.4. Future Modifications

During the implementation workshop held at UNO on May 13-14, 1996, the following modifications of the corrective maintenance window were requested:

1. The "Availability of resources onboard to make the permanent repair in less than a week" section should be renamed "Availability of resources onboard to make the permanent repair."

2. The "location of permanent repair" drop-down menu should be deleted.

3. In the "Failure Type" drop-down menu, "Mechanical Wear" and "Mechanical Fracture" should be deleted and replaced with "Mechanical." The failure type will only include "Mechanical" and "Electrical."

4. In the "Failure Cause" drop-down menu, "Communications Problem" should be deleted and "Normal Wear and Tear" should be replaced with "Abnormal Wear and Tear."

5. The "results of corrective maintenance repair action" drop-down menu should include four types of permanent repair:

- Permanent Repair With No Reduction in Performance,
- Permanent Repair With Complete Overhaul,
- Equipment Replaced - Same Model (Equipment Unrepairable/Inoperable)
- Equipment Replaced - Different Model (Equipment Unrepairable/Inoperable)

These four permanent repair types should replace the current "permanent repair" option. They will disallow the same entries as the current "permanent repair" option. Definitions are given in section A.4.1.

When the user chooses the "permanent repair with complete overhaul" option, a preventive maintenance report should be automatically generated with no additional input from the user. For the preventive maintenance report, the completion date should be the completion date of the corrective maintenance activity. The action type should be "Complete Overhaul." The equipment and voyage information should be the same as for the corrective maintenance activity. The "action details" field of the preventive maintenance report should refer to the corresponding "action details" field of the corrective maintenance report, using the action dates, folder number and repair number. Consequently, the "action details" field of the preventive maintenance report should be as follows:

> "Refer to the following corrective maintenance activity for details:
>
> Start Date:
> End Date:
> Folder #:
> Repair #:"

The user should be asked to provide the identification of the new piece of equipment when it is replaced. This will require the addition of a field which will capture the ID of the new piece of equipment.

6. The corrective maintenance window will include a standard form print-out option. This standard form can be used to capture the necessary information manually during the repair activity. It will be printed from DATE corrective maintenance sub-window.

A.5. Equipment Database Window

A.5.1. Definitions

1. SOCP Equipment (Class) ID / SOCP Equipment Name: Global equipment identifiers for SOCP wide and worldwide data exchange. Under review - To be finalized.

2. Cumulative Running Hours at Data Collection Start Date: the number of hours the equipment has operated between the date that the equipment was installed onboard the vessel and the data collection start date for a specific piece of equipment.

3. Running Hours at Data Collection Start Date: the number of hours the equipment has operated between the last complete overhaul and the data collection start date for a specific piece of equipment. If there was no complete overhaul between the equipment installation date and the DATE program installation date, then enter the "Cumulative Running Hours at Data Collection Start Date" (see above) in this field.

4. Running Hour Percentages: Currently, with each piece of equipment selected for performance tracking, the user enters running time percentages based on four ship operation (voyage) modes. Made by the Chief Engineer, running time percentages are estimates of the percentage of time that a piece of equipment will be running, under normal vessel operating conditions, for a particular vessel operating mode. For example, while the vessel is at sea the main engine would normally operate 100% of the time while critical equipment with redundant back-up would operate 50% of the time. The Running time percentages are used by the program to estimate Running Hours of the equipment at a particular event in time.

A.5.2. Selection Window

The equipment database selection window provides the same searching capabilities as the preventive and corrective maintenance windows. The equipment list can be searched either by equipment name or by equipment ID using the "RETRIEVE" button (see Figure 25).

The selection window includes the following options:

1. choose OK to display, modify or delete existing entries for a specific piece of equipment.
2. choose NEW to add a new piece of equipment in the list.
3. choose SORT to modify the existing selection window sorting option.
4. choose PRINT to print the equipment list.
5. choose HELP to access the on-line help.

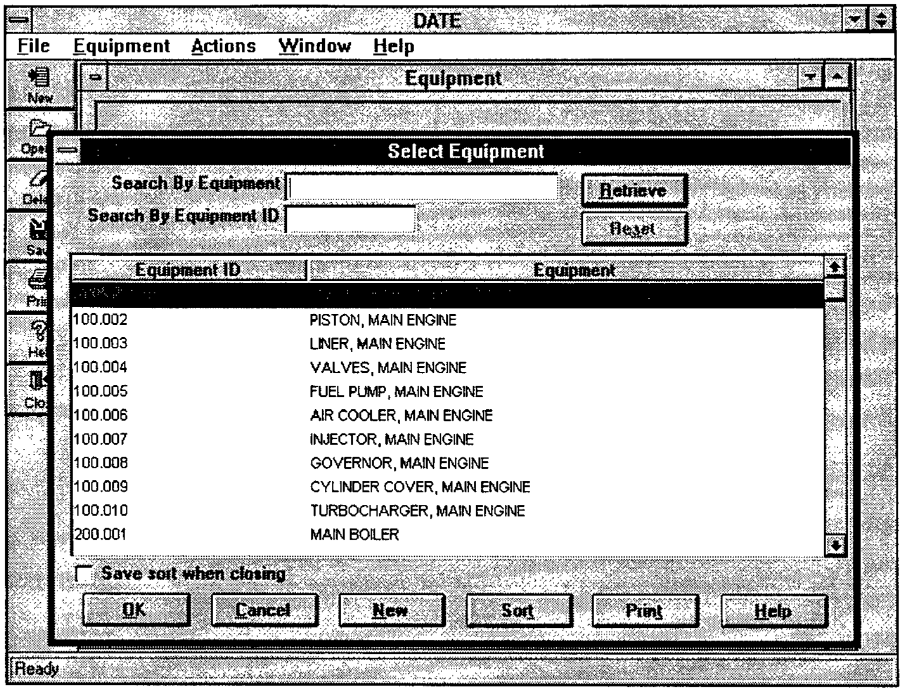

Figure 25 . DATE Equipment Database Selection Window

A.5.3. Main Window

The following information is needed for each piece of equipment (see Figure 26):

- equipment ID
- equipment description
- placed in service date
- serial number
- manufacturer
- model number
- model type
- SOCP ID
- SOCP description
- Memo field for the rest of the equipment name plate data.

The next version of DATE will include a "data collection start date" field that will capture the date at which the data collection starts for each piece of equipment. It will also include a "Company Customizable Equipment Category Code".

Cumulative Running Hours must be estimated and entered in the Equipment Database during DATE setup. From that time period forward, the program will estimate the cumulative running hours of equipment using the equipment Running Time Percentages and vessel voyage information entered by the Chief Engineer. If the Chief Engineer has more accurate equipment running hours information, i.e. due to special equipment operating circumstances or an hour meter is installed, he should over-write the

Cumulative Running Hours displayed in the Preventive or Corrective Maintenance Action windows. The accuracy of Cumulative Running Hours is critical to program operation and the validity of RAM calculations, made by SHIPPER/SPIN for the periods which the user has requested. These programs look at the Cumulative Running Hours at the start and end dates of the time period selected by the user, subtracting them to obtain equipment up time. Equipment up time is a critical element in the calculation of most of the RAM indices.

Initial Cumulative Running Hours and Running Hours have to be entered if the piece of equipment was not new at the installation date. The user can decide to change the operation rates if it is believed that the current estimation in not accurate enough. However, due to some uptime and downtime calculation constraints, the date of the equipment rate modification must correspond to a "marker", which is either a Preventive Maintenance or Corrective Maintenance activity date or a voyage leg start/end date. The existing operation rates can be overridden by clicking on the "Operation Rates" button (see Figure 27).

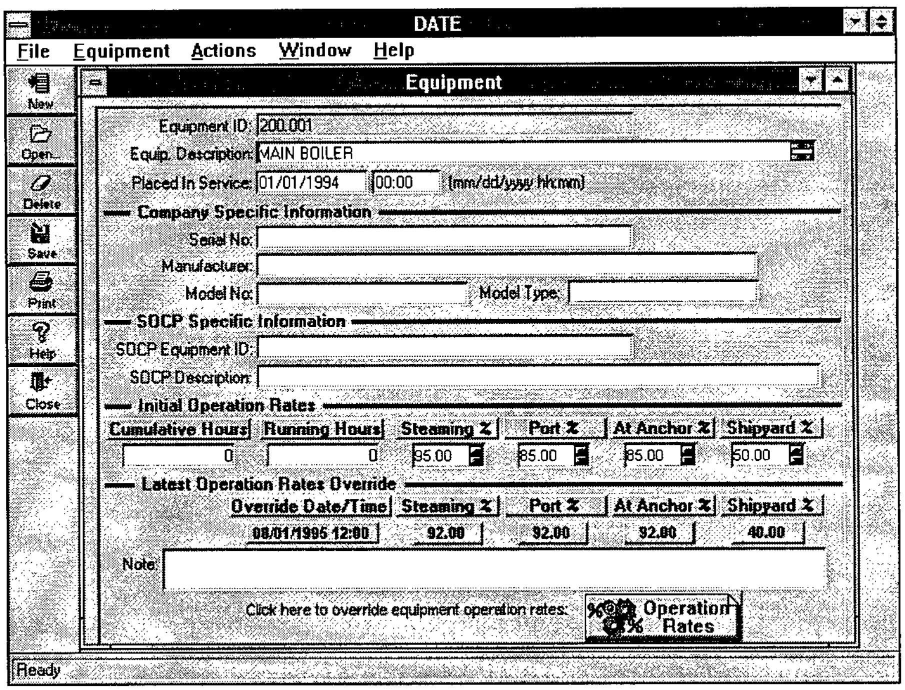

Figure 26 . DATE Equipment Data Entry Window

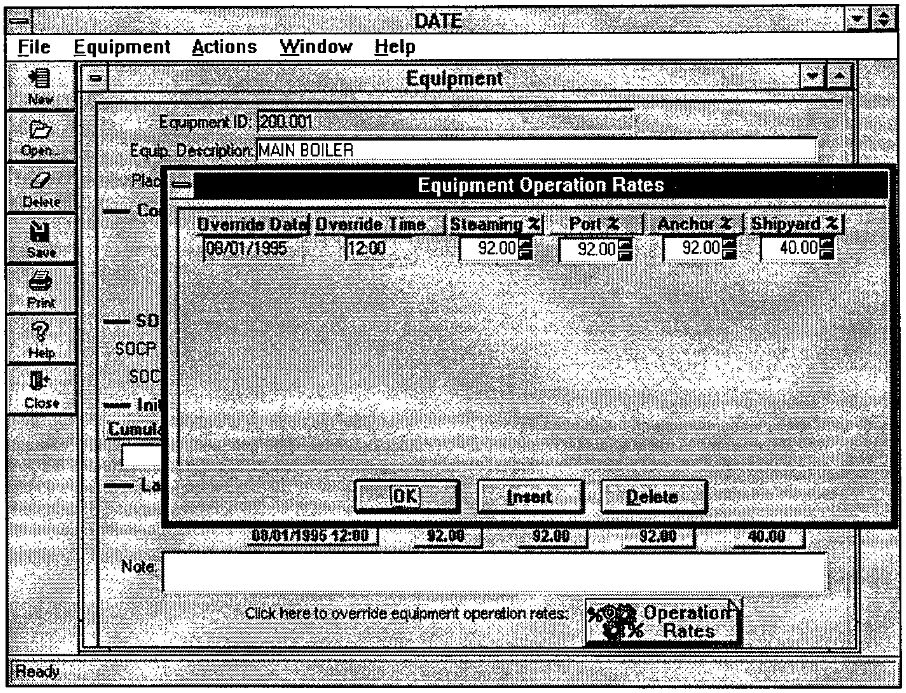

Figure 27 . DATE Equipment Operation Rate Override Window

This opens a new window, which can be closed by clicking on the "OK" button. The "INSERT" button must then be clicked to add a new operation rate override. The user is asked for a date that does not have to be a marker at this point. This is only the date from which the user would like to apply the new rates. After clicking on the "OK" button, DATE displays the markers that are the closest to the date proposed by the user if the user's entry does not coincide with a marker (see Figure 28). One of the proposed dates has to be selected before the user can click "OK" and exit the equipment rate selection date window. The user can then enter the new rates and click on "OK" to go back to the equipment database main window. An equipment rate override can be deleted by selecting it and clicking on the "DELETE" button.

In the equipment data main window, the user can use either the buttons on the left side of the screen or the menu bar to enter a new piece of equipment, to open the selection window, to delete existing entries, to save new entries, to access the print preview or to exit the application.

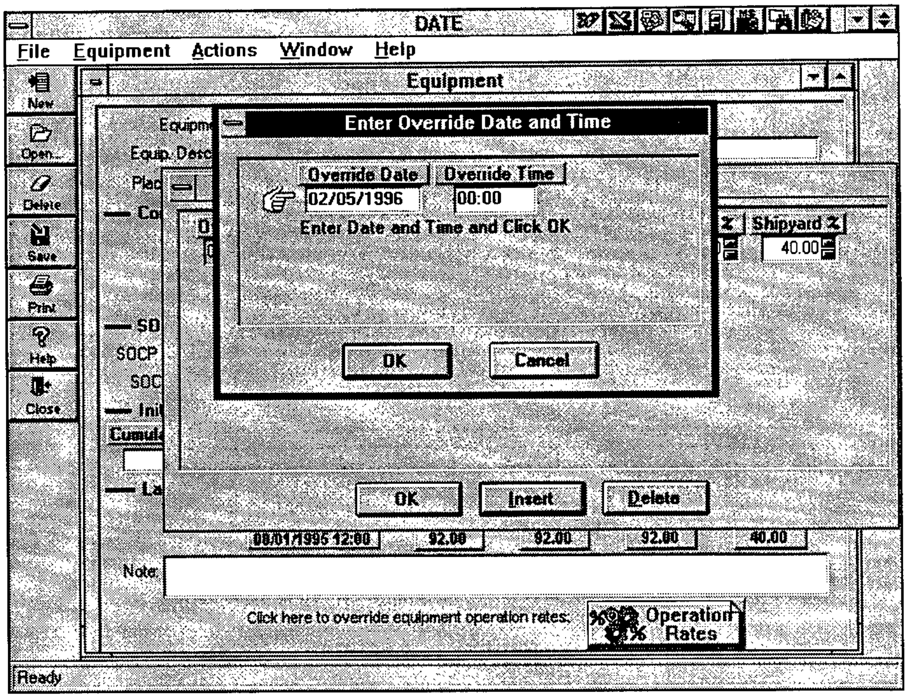

Figure 28 . DATE Date and Time Entry For Equipment Override

A.6. Equipment Class Window

A.6.1. Selection Window

The selection window includes the following options (see Figure 29):

1. choose OK to display, modify or delete an existing equipment class.
2. choose CANCEL to go back to the main window.
3. choose SORT to modify the selection window sorting option.
4. choose PRINT to print the list of equipment classes.
5. choose HELP to access the on-line help.

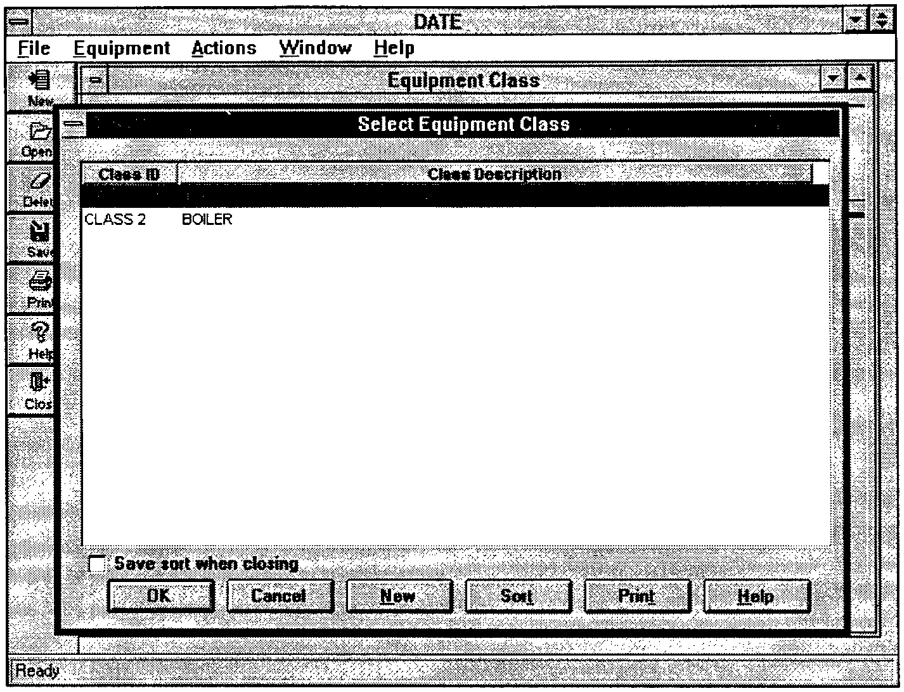

Figure 29 . DATE Equipment Class Selection Window

A.6.2. Main Window

Class ID and class description are required fields of the main equipment class window. A piece of equipment can be removed from an equipment class by selecting it and clicking on the "Remove Equipment" button (see Figure 30).

The user can add pieces of equipment to an equipment class by clicking on the "Open Equipment List" button. This opens the equipment list and allows the user to select the desired pieces of equipment using the mouse or arrow keys. Multiple selection is possible. A piece of equipment is selected by clicking once on the corresponding line and de-selected by re-clicking on the corresponding line. After the selection, the pieces of equipment are added to the equipment class by clicking on the OK button.

From the equipment class main window, the user can use either the buttons on the left side of the screen or the menu bar to create a new equipment class, to open the selection window, to delete existing entries, to save new entries, to access the print preview or to exit the application.

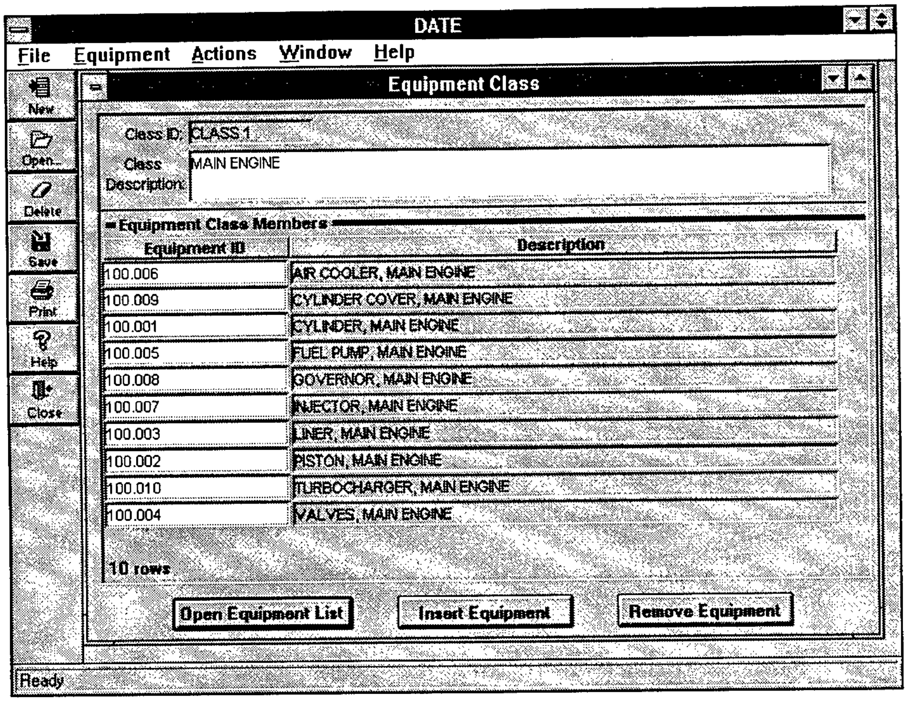

Figure 30 . DATE Equipment Class Entry Window

A.7. General Features

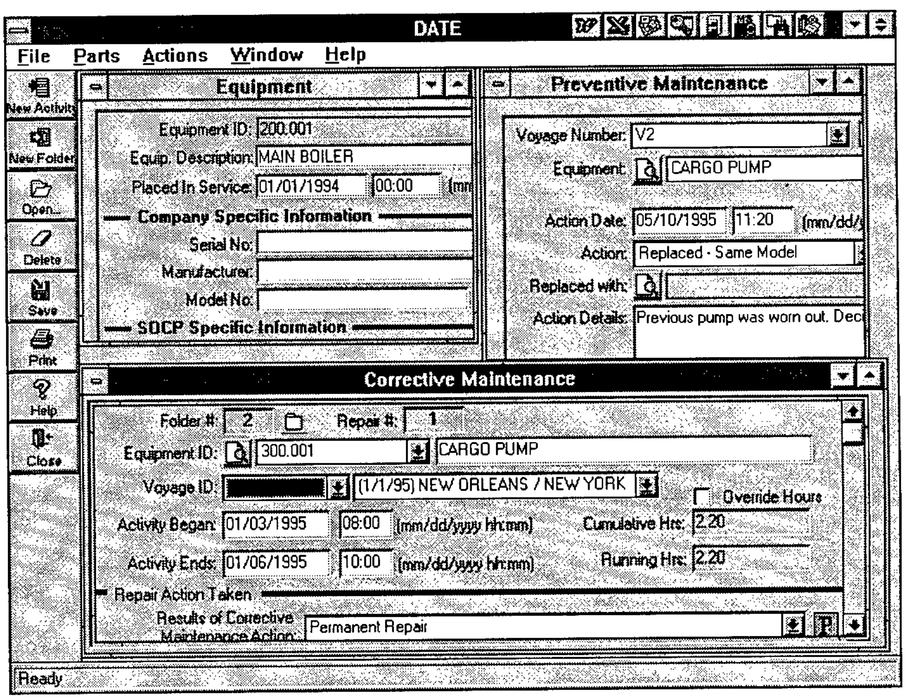

Figure 31 . DATE Simultaneous Window Opening

Several DATE sub-windows can be opened simultaneously (see Figure 31). While working on a sub-window, one can access another sub-window by using the "actions" option of the menu bar (see Figure 32). One can switch from one window to the other by using the "windows" option of the menu bar. Only one window of a kind can be open at the same time. For example, it is not possible to open two preventive maintenance windows.

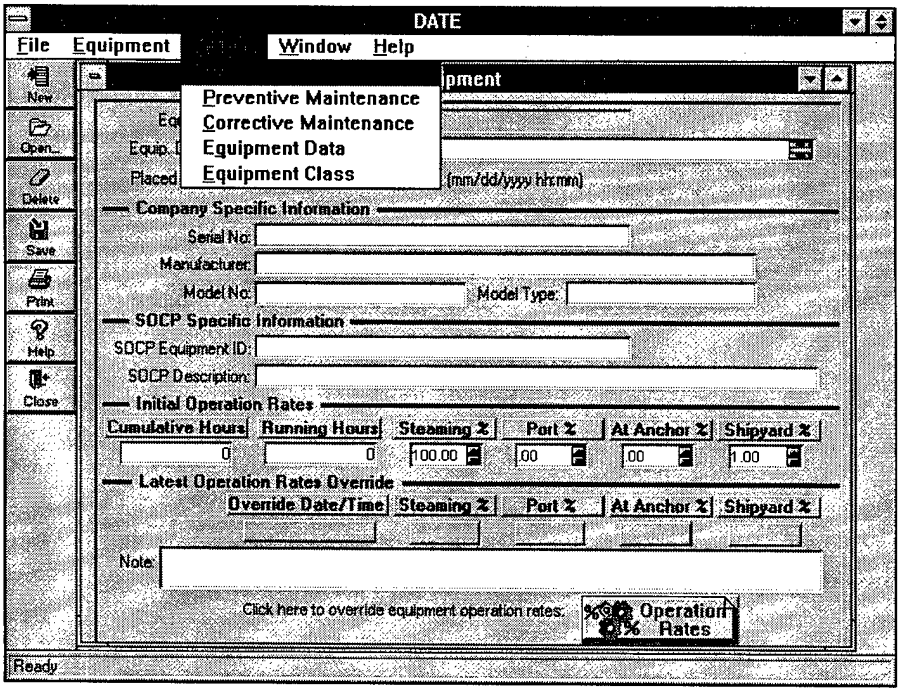

Figure 32 . DATE Action Selection

Every sub-window can be minimized using the down arrow on the top right corner of the screen. It can be enlarged to its original size by double-clicking on the icon. The sub-window size can be customized by using the mouse and the two-way arrows on every border of the screen (see Figure 33).

The on-line help can be accessed from any DATE screen. The displayed topic corresponds to the screen from which the help is called, but the user can access any topic by using the "CONTENT" button (see Figure 34). Words in green letters indicate that a definition or additional details and comments can be obtained on the topic. When cursor turns from an arrow into a finger symbol, then click on the text to view the additional information.

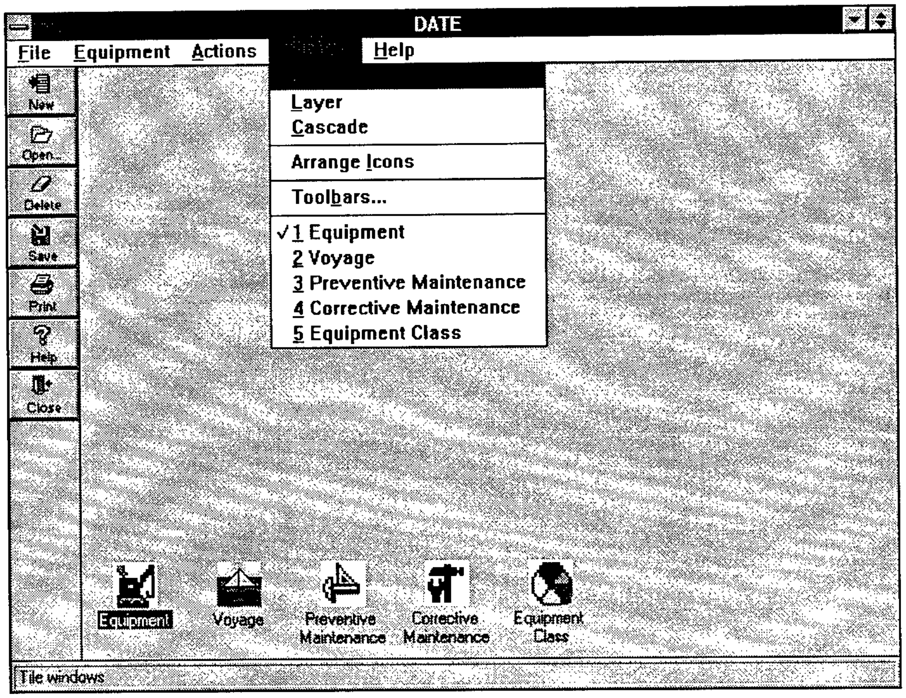

Figure 33 . DATE Action Icons

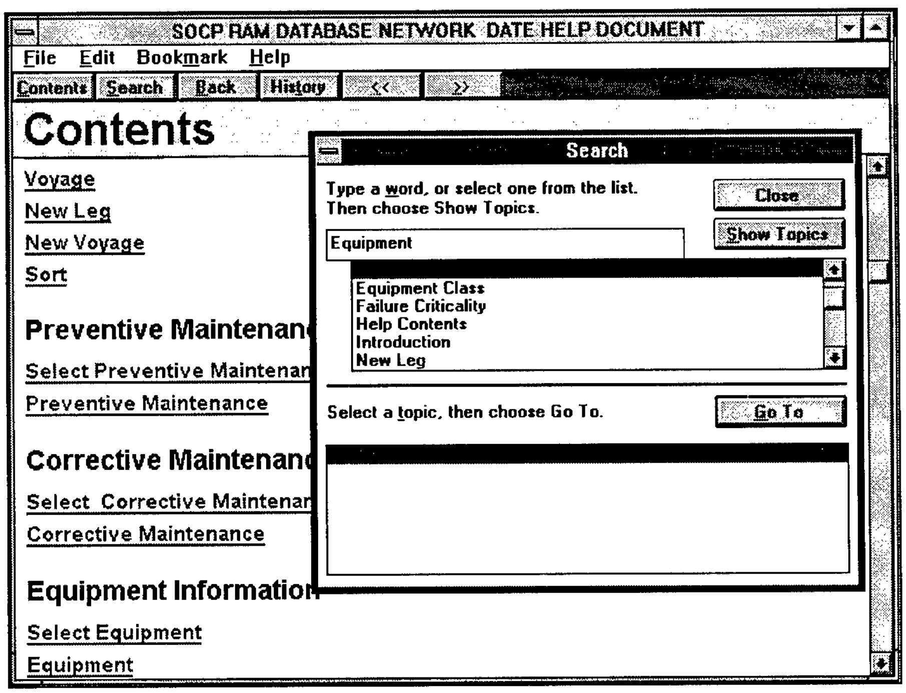

Figure 34. DATE on-line Help

APPENDIX B
DESCRIPTION OF SHIPPER VERSION 2.0 BETA

B.1. Introduction

SHIPPER features are similar to DATE general features. SHIPPER includes two main options (see Figure 35):

1. Performance Analysis
2. Time Line Analysis

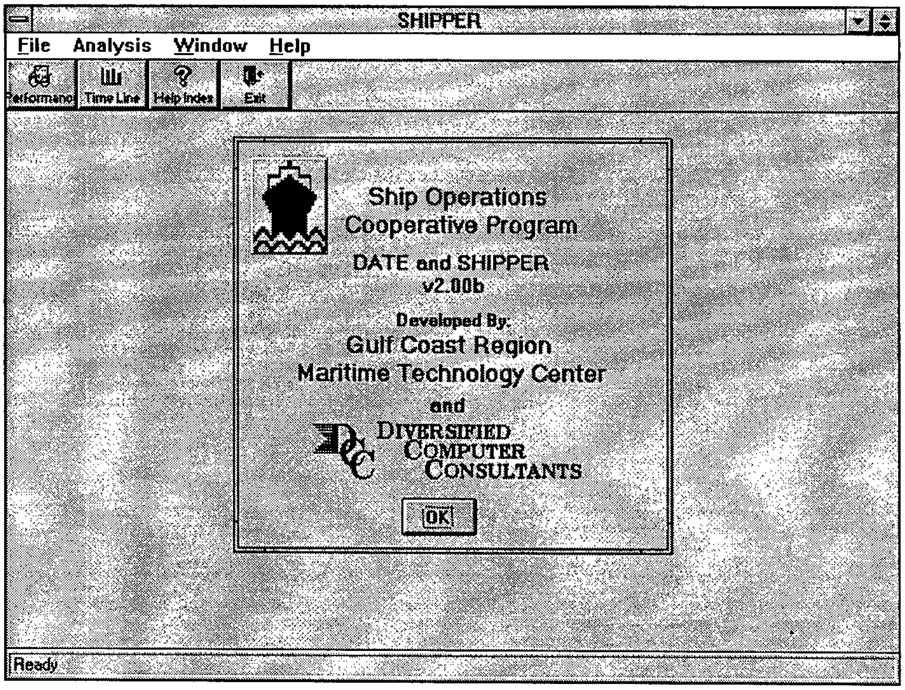

Figure 35 . SHIPPER Start-Up Window

The performance analysis provides the user with 14 RAM (Reliability, Availability and Maintainability) performance indicators, which evaluate the performance of on-board equipment. The time line analysis allows the user to display the complete maintenance history of selected pieces of equipment. This includes voyage information, preventive maintenance, corrective maintenance and operation rates.

B.2. Performance Analysis

The performance analysis window can be accessed either by clicking on the "PERFORMANCE" button of the main menu or by using the menu bar. The performance analysis is performed over a certain period of time that the user chooses (see Figure 36).

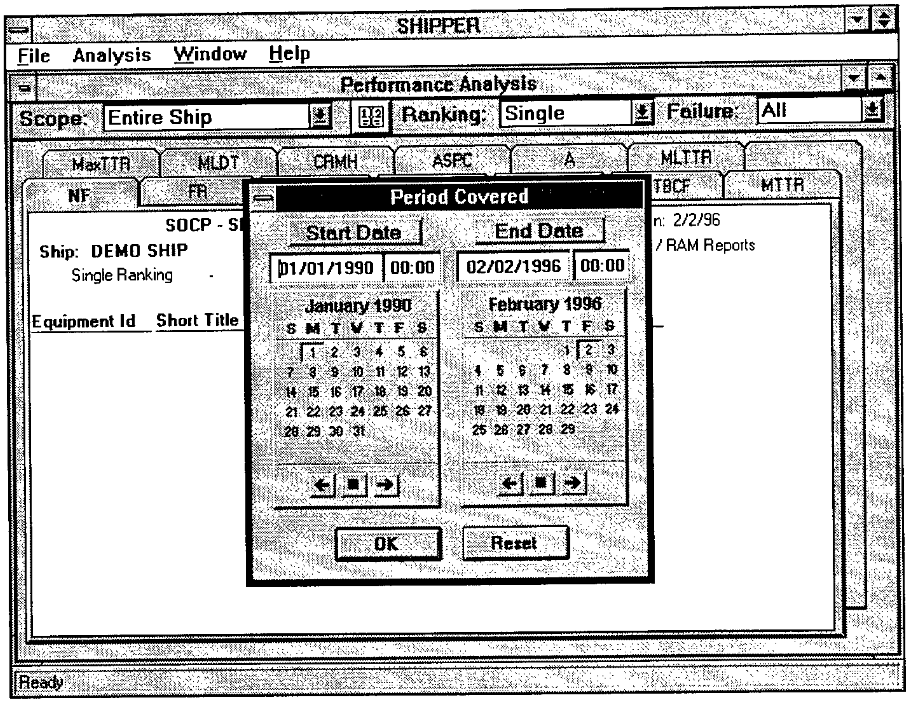

Figure 36 . SHIPPER Date Selection

The window was built using a file folder type display. The default performance indicator that is displayed is the number of failures (see Figure 37).

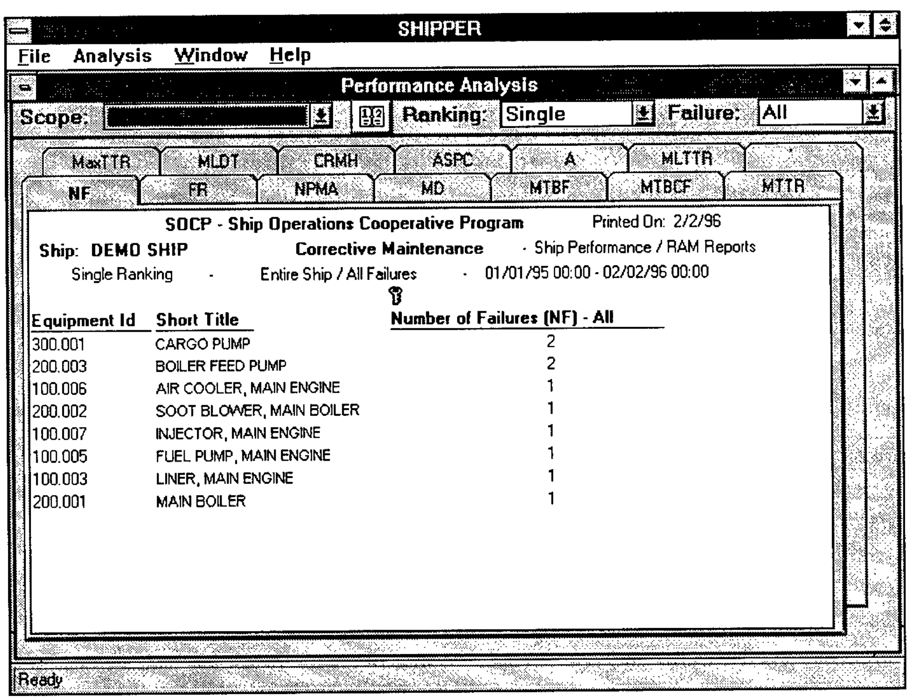

Figure 37 . SHIPPER Main Window For Performance Analysis

The user can choose another performance indicator by clicking on the corresponding folder tab. Calculations may require a few seconds.

SHIPPER includes the following three options for the scope of the study:

- entire ship
- equipment class
- single equipment

Selection is made using a drop down menu (see Figure 38). If the "single equipment" option is chosen, the same equipment searching capabilities as in DATE are offered.

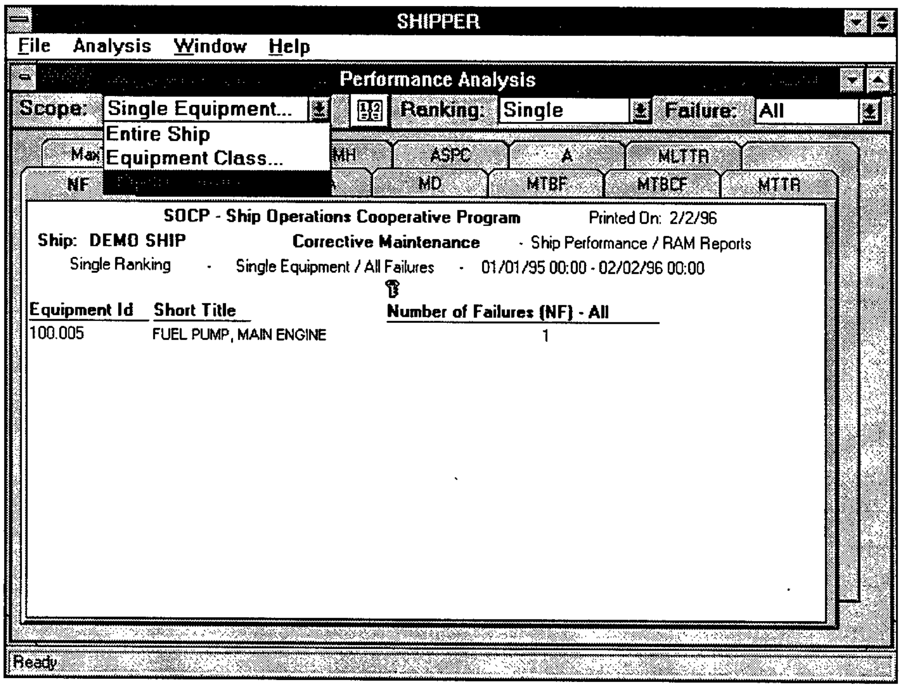

Figure 38 . SHIPPER Performance Analysis: Scope Selection

The report dates can be changed by clicking on the red calendar icon that is on the right of the scope button.

There are two possible rankings:

- single ranking
- comparative ranking

The single ranking is the default option and shows the performance indicators individually using the folder type display. The comparative ranking displays simultaneously all the performance indicators (see Figure 39).

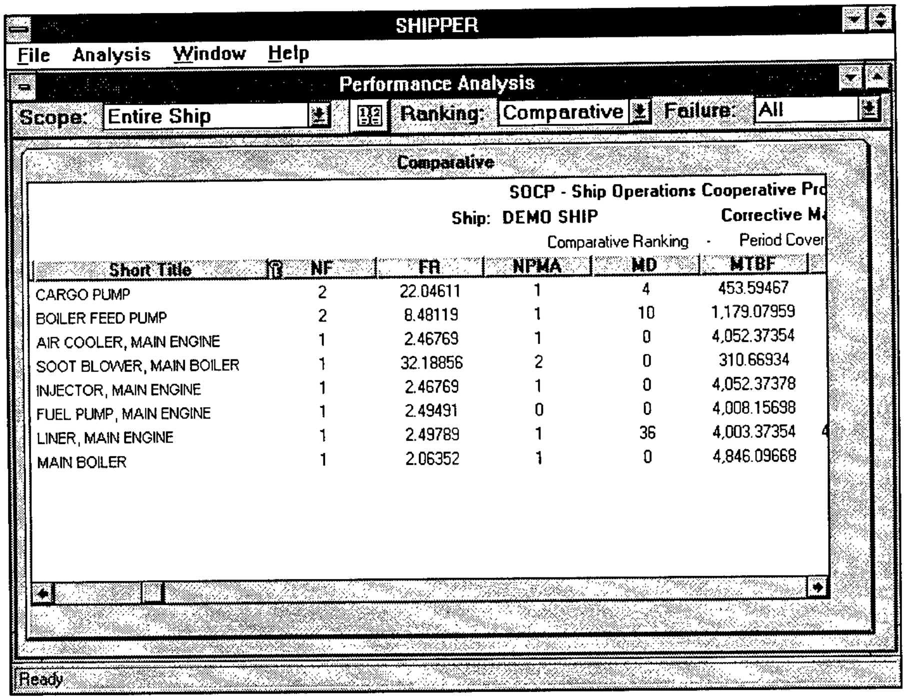

Figure 39 . SHIPPER Performance Analysis: Comparative Ranking

By default, pieces of equipment are sorted by number of failures. The user can change the sorting by clicking on the name of the desired performance indicator by which he/she would like the pieces of equipment to be sorted. The yellow key indicates the performance indicator that sorts the piece of equipment. The user can switch from single to comparative ranking using the drop down menu. Upon user's selection, all failures can be displayed for critical, major or minor failures only. Selection is made using a drop down menu (see Figure 40). The following is a description of the thirteen performance indicators provided by SHIPPER.

B.2.1. Number of Failures (NF)

The number of failures is the number of failures over the period of time covered by the report dates, with the exception of failures under temporary repair [no unit]. By double-clicking on the value of NF, the user can display a sub-report that gives additional information on the failures (see Figure 41).

B.2.2. Failure Rate (FR)

The failure rate in failures per hour is the ratio between the number of failures and the uptime derived over the period of time covered by the report dates. SHIPPER provides the failure rate per 10,000 hours. No sub-report is available from this folder.

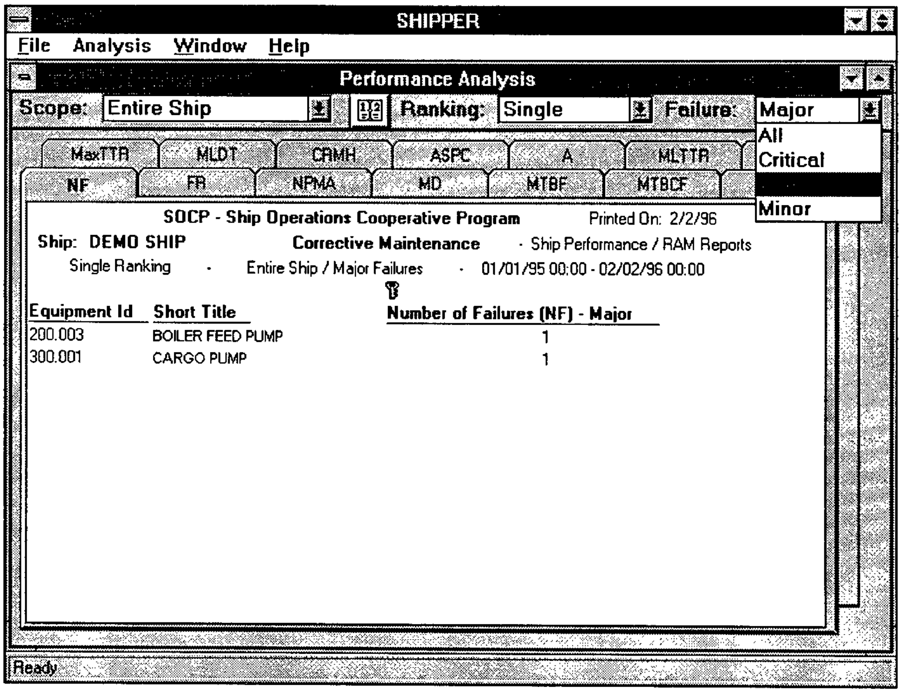

Figure 40 . SHIPPER Failure Type Selection

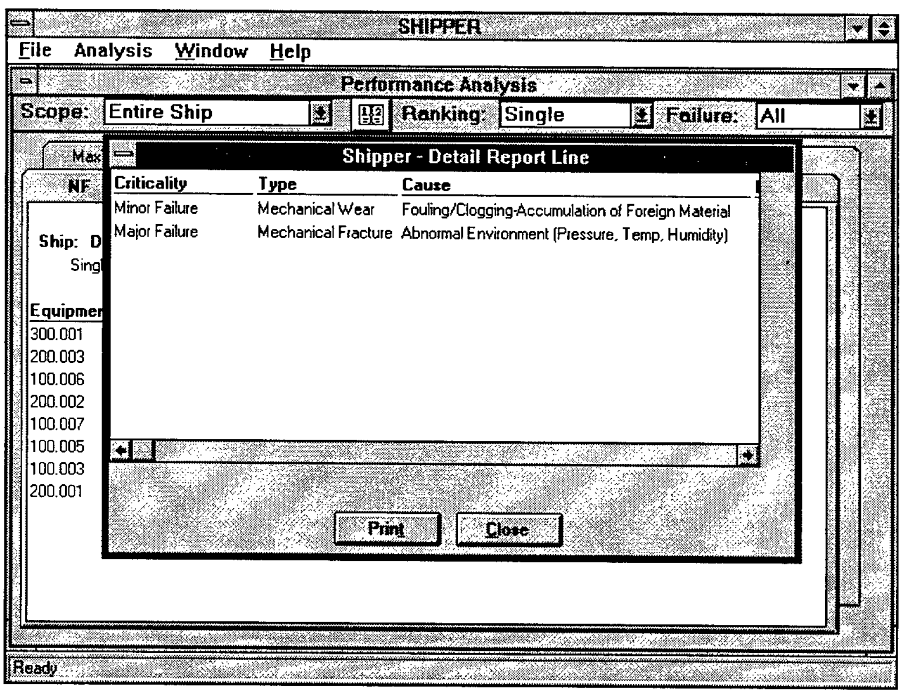

Figure 41 . SHIPPER Number of Failure Sub-Report

B.2.3. Number of Preventive Maintenance Activities (NPMA)

The number of preventive maintenance activities is the number of preventive maintenance actions over the period of time covered by the report dates. No sub-report is available.

B.2.4. Mission Delays (MD)

The mission delay is the sum of the delays that are entered in the field "Total Mission Delay" of the corrective maintenance report [in hours]. No sub-report is available from this folder.

B.2.5. Mean Time Between Failures (MTBF)

The mean time between failures is the ratio between the uptime and the number of failures over the period of time covered by the report dates [in hours]. By double-clicking on the MTBF value, the user can display a sub-report that gives MTBF for all, critical, major and minor failures (see Figure 42).

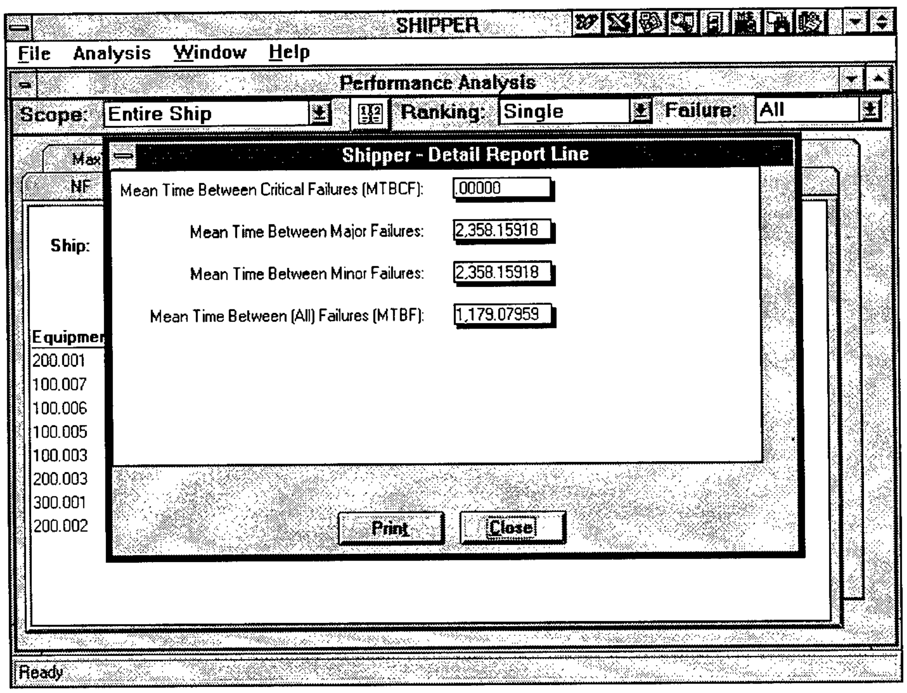

Figure 42 . SHIPPER Mean Time Between Failures Sub-Report

B.2.6. Mean Time Between Critical Failure (MTBCF)

The mean time between critical failures is identical to the average time between failures, but the uptime and the number of failures are only counted for critical failures [in hours]. No sub-report is available.

B.2.7. Mean Time To Repair (MTTR)

The mean time to repair is the ratio between the cumulative time to repair and the number of failure over the period of time covered by the report dates [in man hours]. Sub-report shows the reason for repair and when the need for repair was discovered (see Figure 43). A second sub-report is available under "during regulatory, customer, or company required inspection" which gives inspection details (see Figure 44).

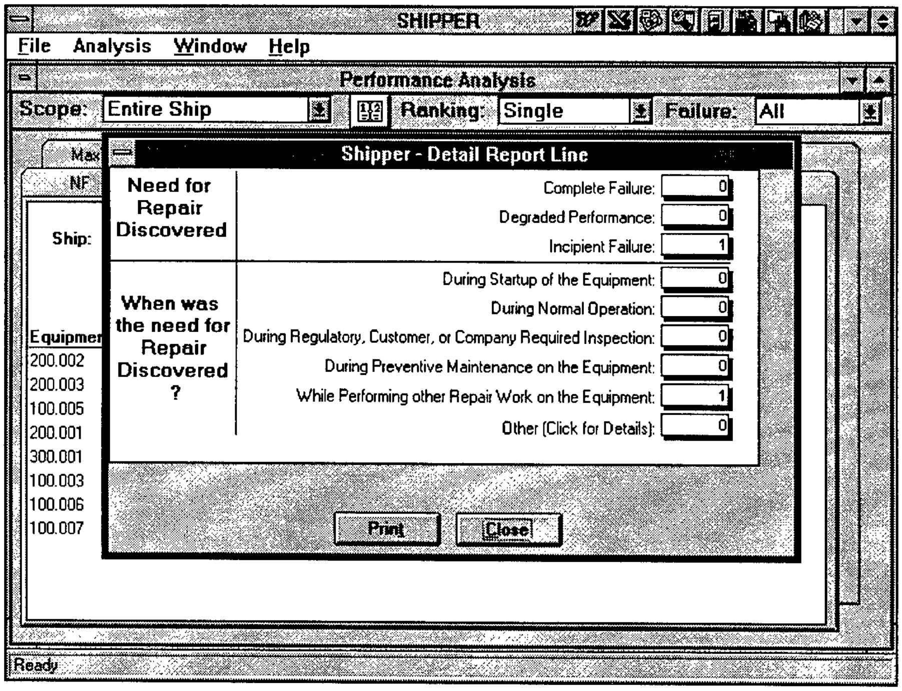

Figure 43 . SHIPPER Mean Time To Repair Sub-Report

B.2.8. Maximum Time To Repair (MaxTTR)

The max time to repair is the maximum time to repair over the period of time covered by the report dates [in man hours]. No sub-report is available.

B.2.9. Mean Logistic Delay Time (MLDT)

The mean logistic delay time is the mean delay time when resources are unavailable. The delay time is entered in the "Total Delay" field of the Corrective Maintenance report [in hours]. Sub-report shows the frequency of the various delays (see Figure 45).

B.2.10. Cumulative Repair Man Hours (CRMH)

The cumulative repair man hours are the addition of the repair man hours over the period of time covered by the report dates [in man hours]. No sub-report is available.

B.2.11. Average Spare Parts' Cost (ASPC)

The average spare parts' cost is the ratio between the cumulative spare parts' cost and the number of failures over the period of time covered by the report dates [in dollars]. Sub-report shows the average and cumulative spare parts' costs (see Figure 46).

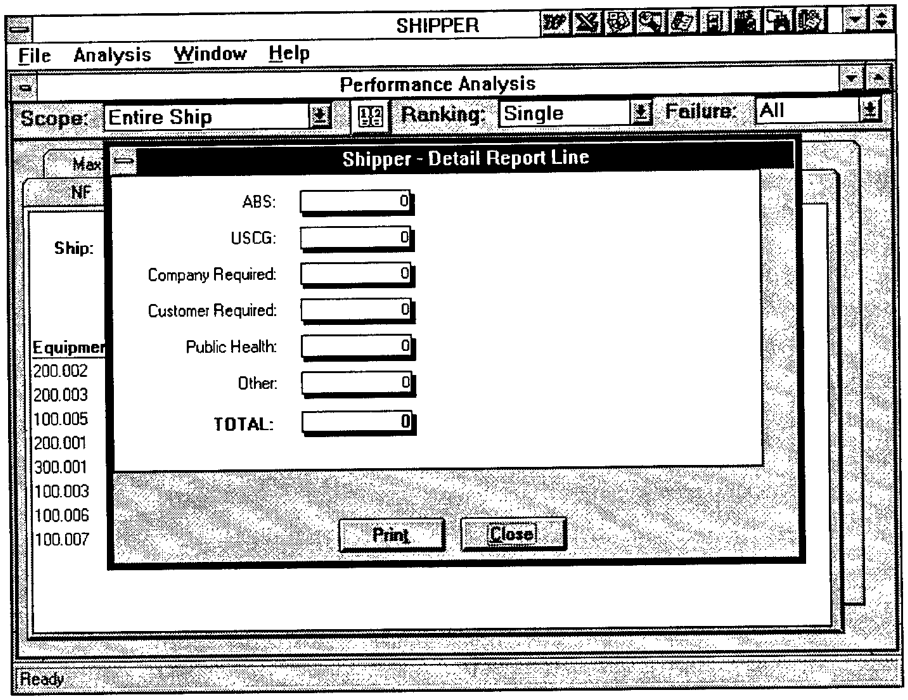

Figure 44 . SHIPPER Mean Time To Repair Second Sub-Report

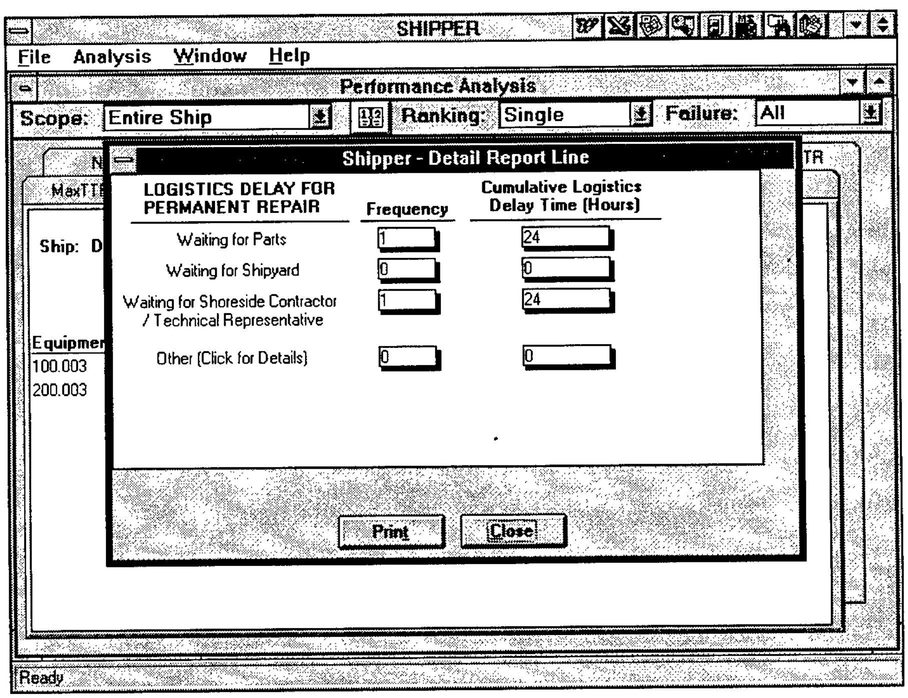

Figure 45 . SHIPPER Mean Logistic Delay Time Sub-Report

B.2.12. Mean Lapsed Time To Repair (MLTTR)

For each corrective maintenance activity, the Lapsed Time To Repair (LTTR) is the difference between the date of the first repair activity and the date of the activity that

resulted in a permanent repair. Lapsed time to repair is not counted unless the repair job is completed by a permanent repair. The mean lapsed time to repair is the ratio between the cumulative lapsed time to repair and the number of failures over the period of time covered by the report dates [in hours]. No sub-report is available.

B.2.13. Availability (A)

The operational availability A_1 (AMR) is based on the mean time to repair man hours. The operational availability A_2 (ALR) is based on the mean lapsed time to repair. No sub-report is available. The formulation is the following:

$$A_1 = \frac{MTBF}{MTBF + MTTR + MLDT}$$

$$A_2 = \frac{MTBF}{MTBF + MLTTR + MLDT}$$

The user can print a report using the file option of the menu bar. Print-outs are identical to what is displayed on the screen.

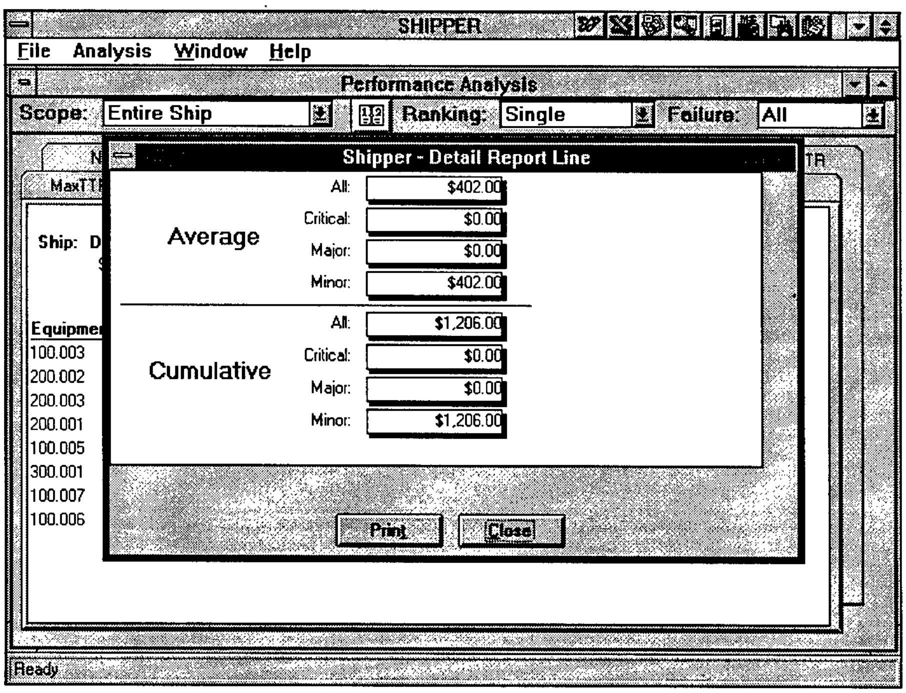

Figure 46 . SHIPPER Average Spare Parts' Cost Sub-Report

B.3. Time-line Display

The time-line analysis can be accessed using the "Time Line" button or the analysis option of the menu bar. Similar to the performance analysis, the user is first asked for report dates. The following two main options are available (see figure 47):

- tabular time line display
- graphical time line display

One can switch from one to the other by using the drop down menu on the top right corner of the screen. By default, the tabular option is displayed. The options for the scope of the study are the same as for the performance analysis. The following types of activity can be displayed:

- all activities, which include preventive maintenance, corrective maintenance and equipment rate overrides.
- failures only, i.e. corrective maintenance activities only.
- temporary repairs only, i.e. corrective maintenance activities that resulted in a temporary repair.
- permanent repairs only, i.e. corrective maintenance activities that resulted in a permanent repair.

Similar to the performance analysis, the user can display all failures, or critical, major or minor failures only.

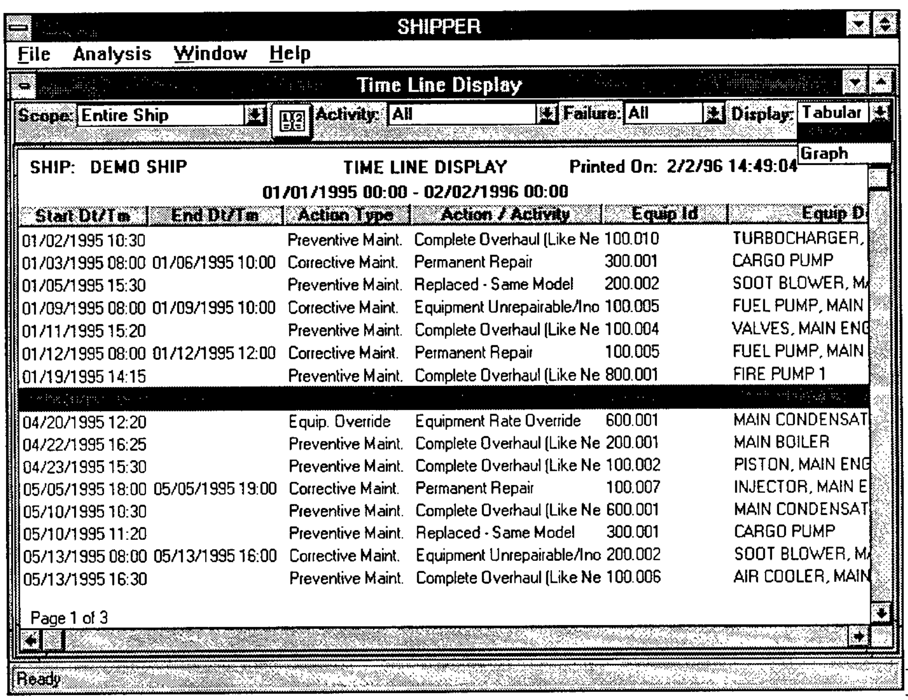

Figure 47 . SHIPPER Time Line Tabular Display

B.3.1. Tabular Display

The user can get a full description of each activity that is displayed by double-clicking on the corresponding line. This opens either the preventive maintenance window, or the corrective maintenance window or the equipment database window for equipment rate overrides (see Figures 48 & 49). At this point, it is not possible to modify any entry. Entries can only be modified by using DATE. The user can print a report by selecting "print" under the file option of the menu bar.

B.3.2. Graphical Display

From top to bottom, the graph option shows the following (see Figure 50):

1. report options
2. graphical time line
3. tabular time line

The graph is displayed over a certain period of time (30 days by default). The user can move forward and backwards by using the arrows (<< for backwards and >> for forward). The duration of the period of time displayed on one screen can be changed by clicking on the "ZOOM" button. The user can choose 10 days, 30 days, 60 days, 90 days or can enter any value using the "customize" option (see Figure 51).

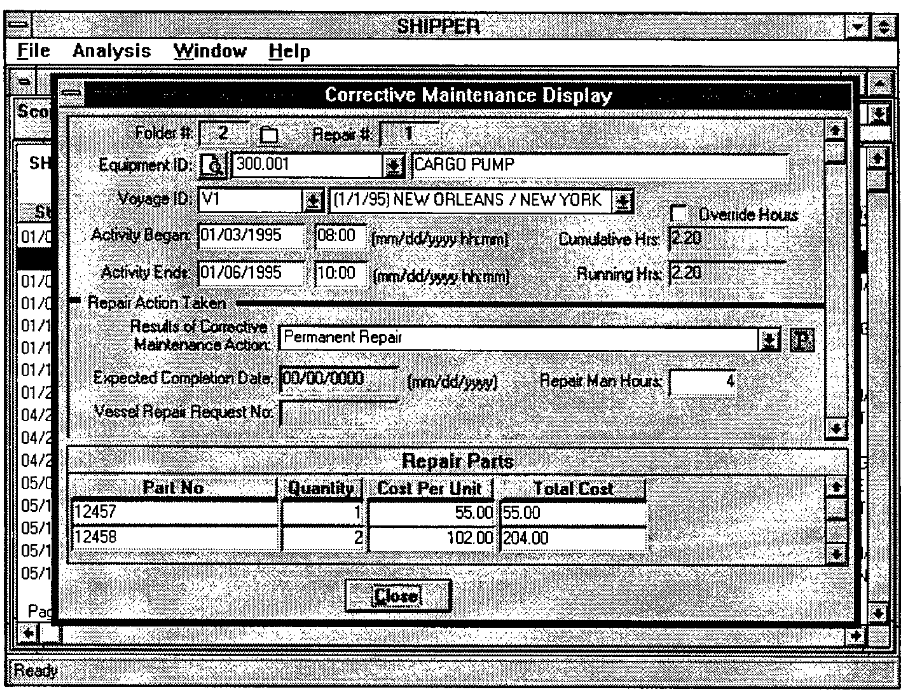

Figure 48 . SHIPPER Corrective Maintenance Display for Tabular Time Line

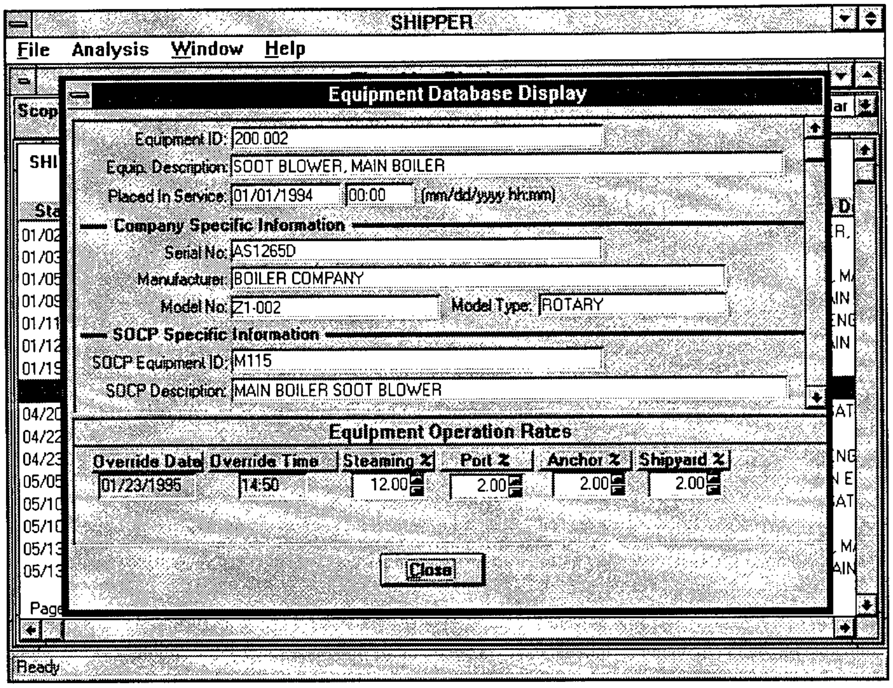

Figure 49 . SHIPPER Equipment Database Display for Tabular Time Line

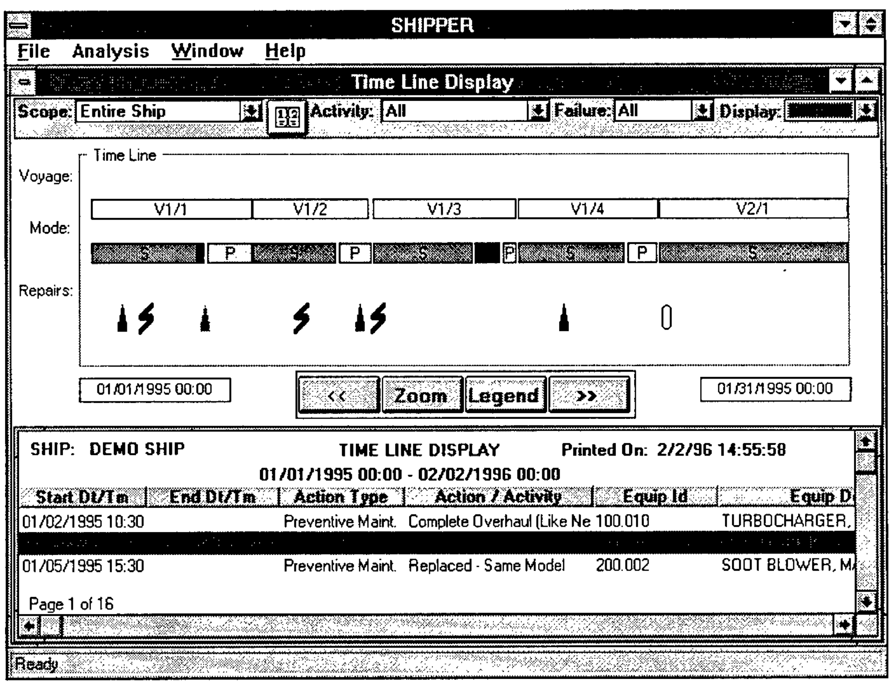

Figure 50 . SHIPPER Graphical Time Line Display

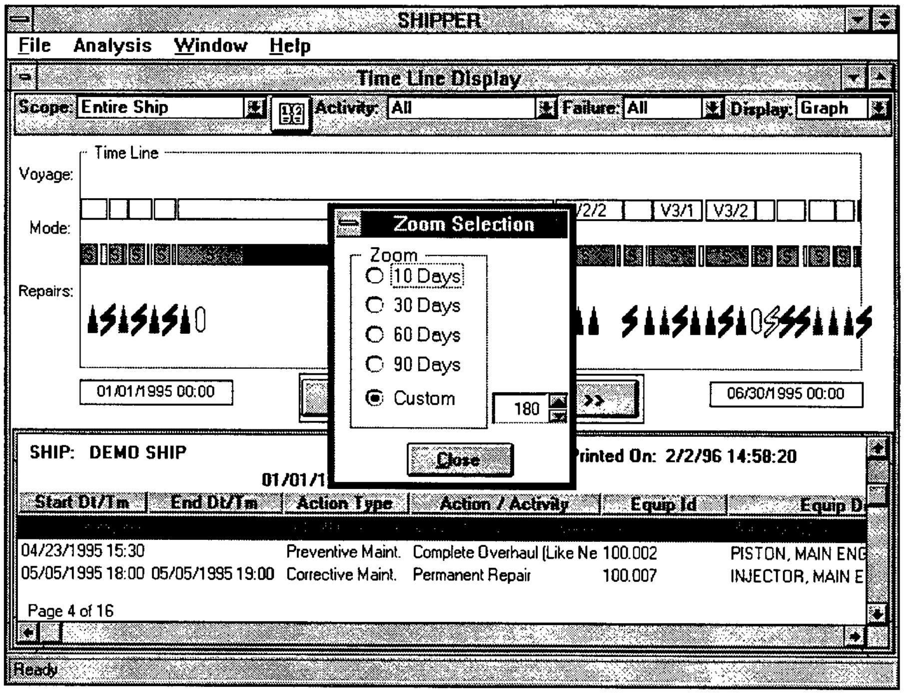

Figure 51 . SHIPPER Time Line Display: Zoom Selection

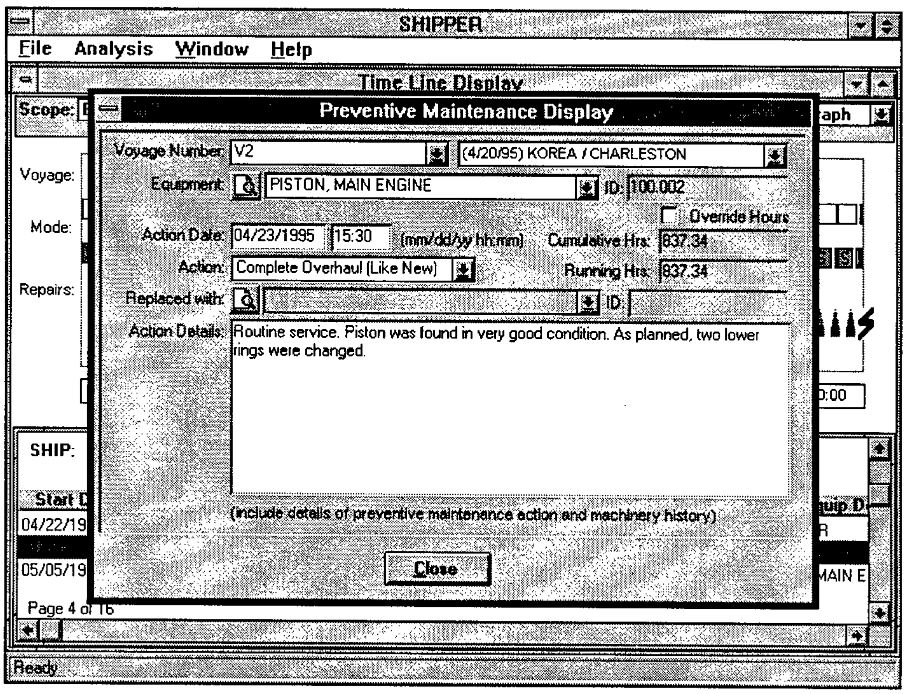

Figure 52 . SHIPPER Preventive Maintenance Display for Graphical Time Line

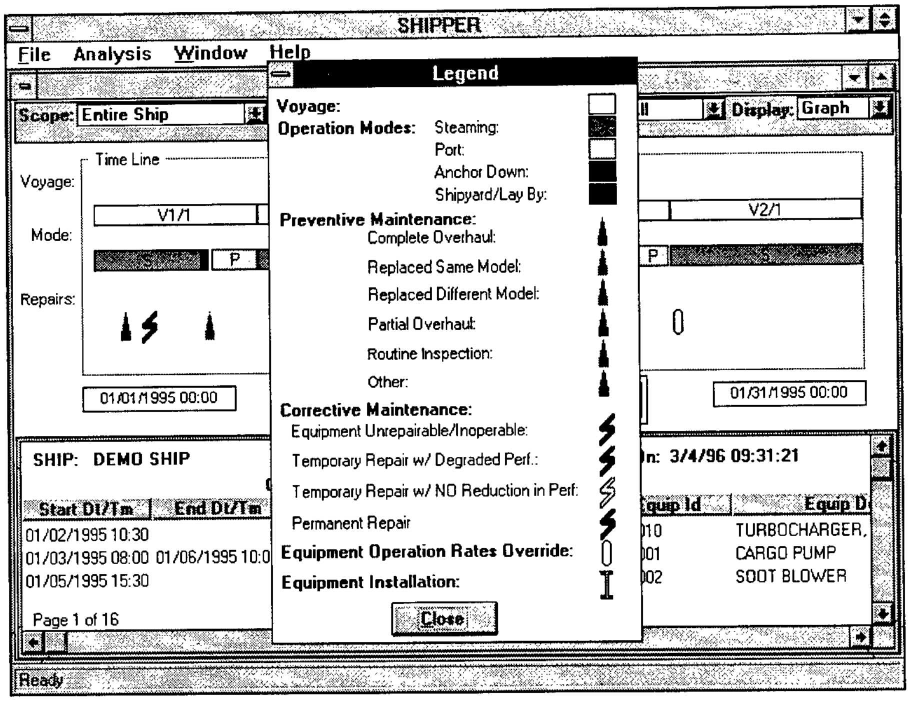

Figure 53 . SHIPPER Time Line Display: Legend

The graph shows the following information:

- voyage information: voyage ID and leg number. If the user double-clicks on the box that represents a voyage leg, the complete voyage information is displayed (see Figure 52).
- operation mode: green for steaming, yellow in port, red at anchor and blue at the shipyard.
- repairs: each type of repair is associated with a specific symbol. At any time, the user can display the legend by clicking on the "LEGEND" button (see Figure 53).

SHIPPER automatically determines whether the information can be displayed or not. If the voyage box is too small to fit the voyage ID and leg number, SHIPPER chooses not to display the information. If the operation mode box is too small to fit one character (S for Steaming, P for Port, A for Anchor and Y for shipYard), SHIPPER decides not to display a character to the box (see Figure 54).

If the user clicks on a repair symbol (see Figure 55), a vertical line indicates the exact location of the repair and the line that corresponds to the repair is shown in blue on the tabular display (bottom of the screen) . To get a complete activity report, the user can double-click either on the symbol or on the blue line on the tabular display (see Figure 56).

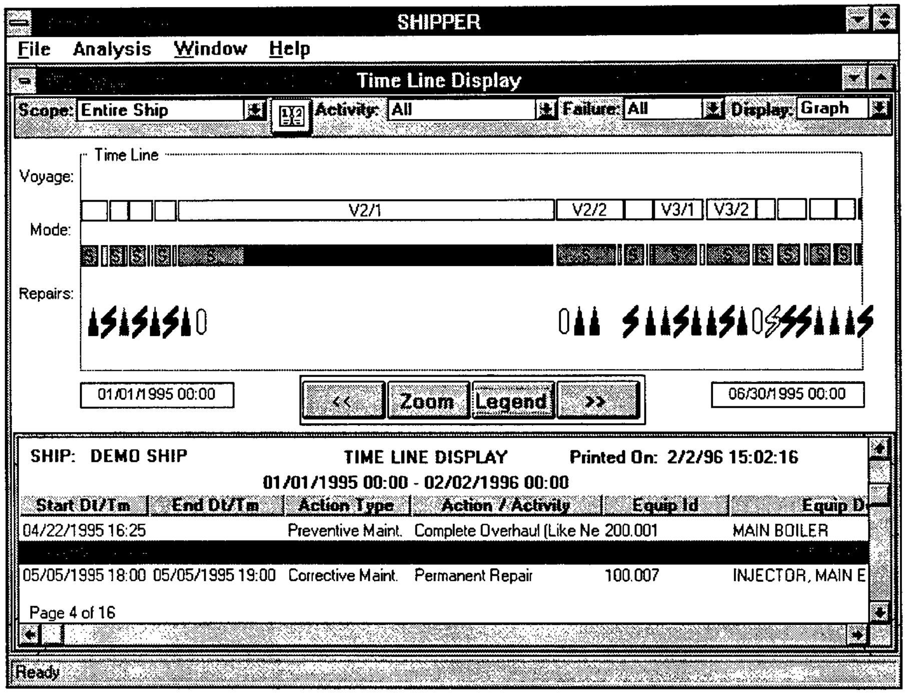

Figure 54 . SHIPPER Example of a Time Line Display

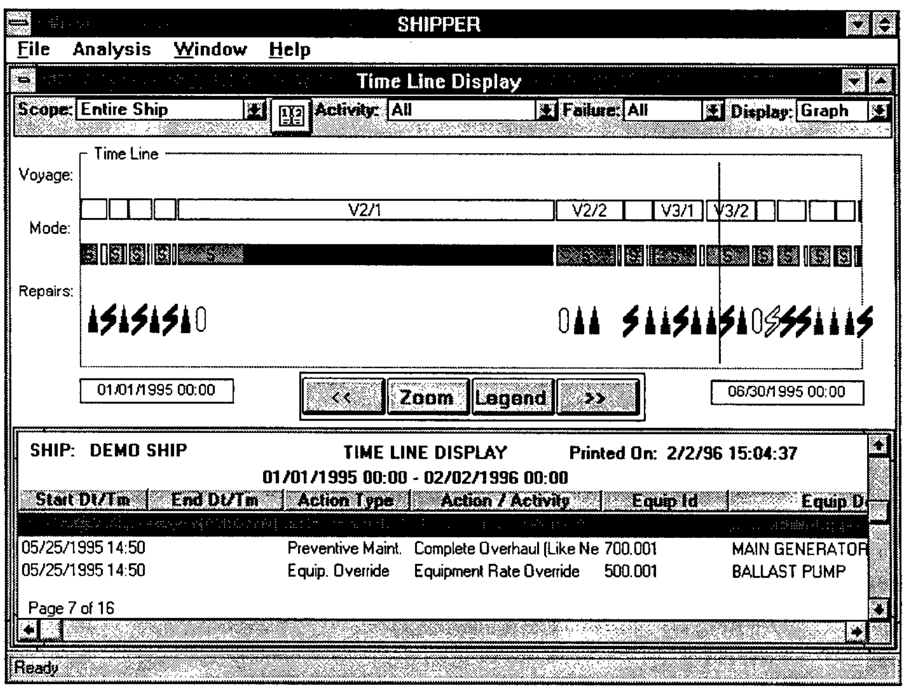

Figure 55 . SHIPPER Location of Action on Time Line Display

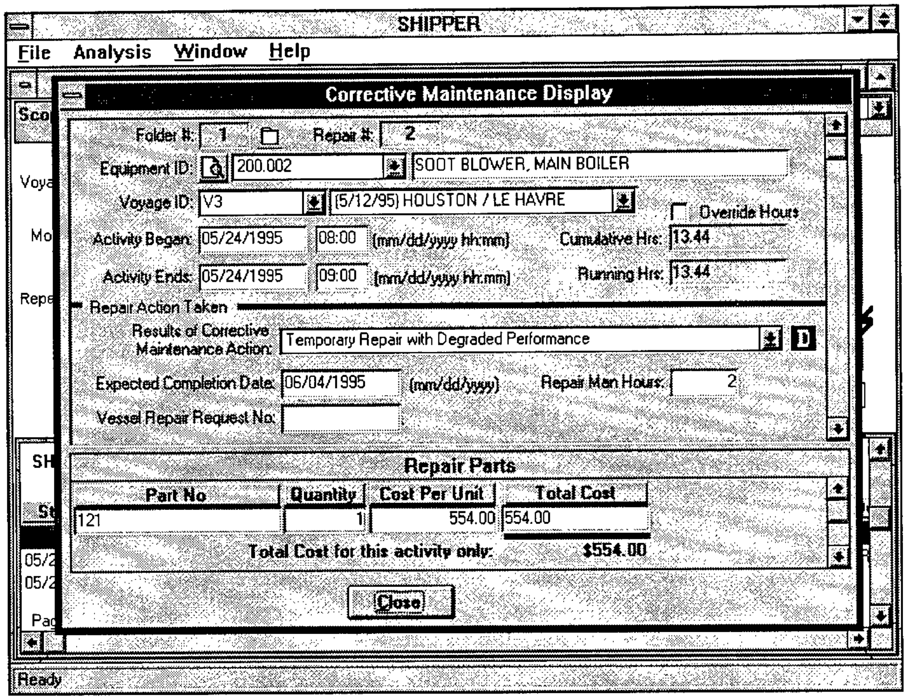

Figure 56 . SHIPPER Corrective Maintenance Display for Graphical Time Line

The user can get a picture of the screen by selecting "print" under the file option of the menu bar. This may require some margin adjustments on the printer set-up.

B.4. General Features

Several SHIPPER sub-windows can be opened simultaneously. While working on a sub-window, one can access another sub-window by using the "analysis" option of the menu bar. One can switch from one window to the other by using the "windows" option of the menu bar. Only one window of a kind can be open at the same time (for instance, it is not possible to open two performance analysis windows).

Every sub-window can be minimized using the down arrow on the top right corner of the screen. It can be enlarged to its original size by double-clicking on the icon. The sub-window size can be adjusted to the users convenience by using the mouse and the two-way arrows on every border of the screen.

The on-line help can be accessed from any SHIPPER screen using the menu bar. The displayed topic corresponds to the screen from which the help is called, but the user can access any topic by using the "CONTENT" button. Words in green indicate that a definition or additional details and comments can be obtained by clicking on them. The pointer will change from an arrow to a hand as a reminder.

APPENDIX C
MANUFACTURER MATCHING

MANUFACTURER	Company A	Company B	Company C
A.C. HOYLE	Y	N	N
AALBORG	N	Y	N
ACME ELECTRICAL MFG. CO	N	Y	N
ACR ELEC.	N	Y	N
AEROFIN CORP	Y	N	N
AIRSTAR	N	Y	N
AIRTEMP DIV CHRYSLER	Y	N	N
ALDEN	Y	N	N
ALEXANDER IND	Y	N	N
ALFA LAVAL	N	Y	N
AMERICAN STANDARD	Y	N	N
AMETEK	Y	N	N
AMF CUNO	Y	N	N
ANDALE CO	Y	N	Y
ANDERSON GREENWOOD AND NEWCO	N	N	Y
AQUA CHEM	Y	N	Y
ARMSTRONG	N	N	Y
ASCO	Y	N	N
ASI INSTRUMENTS	N	Y	N
ATLAS COPCO INC	Y	N	N
ATWOOD & MORRILL	N	N.	Y
AUDION ELEKTRO	Y	N	N
AURORA PUMP DIV	Y	N	Y
BABCOCK BRISTOL	Y	N	N
BALDOR ELECTRIC	Y	N	N
BARBER-COLMAN	N	N	Y
BECKMAN INSTRUMENTS, INC.	N	N	Y
BEEBE BROS. INC.	Y	N	N
BEECH RUSS	Y	N	N
BENDIX	Y	N	N
BETHLEHEM STEEL	Y	N	N
BETTIS, ORTMAN	Y	N	N
BLACKMER	N	Y	N
BOLL & KIRCH	N	Y	N
BOLL FILTER CORP.	N	Y	N
BROLIC	N	N	Y
BUFFALO FORGE	Y	N	Y
BULL & ROBERTS	N	N	Y

MANUFACTURER	Company A	Company B	Company C
BULLARD	N	N	Y
CAI	Y	N	N
CARLISLE & FINCH	N	N	Y
CARRIER	Y	Y	Y
CARROL-JAMIESON	Y	N	N
CARTER	N	N	Y
CASH	Y	N	Y
CATERPILLAR	Y	N	N
CEMLINE	N	Y	N
CENTRITECH CORP	Y	N	N
CHICAGO HEATER CO	Y	N	N
CHRYSLER AIRTEMP	Y	N	N
CHUD KOGYO CO. LTD.	N	Y	N
COASTAL OIL&FILT	Y	N	N
COFFIN FMC	Y	N	N
COMBUSTION ENGR	Y	N	N
COPES VULCAN	Y	N	N
COPPUS ENGINEERING	Y	N	N
CRANE CO.	Y	N	N
CROSBY VALVE CO	Y	N	Y
CUMBERLAND ENG.	Y	N	N
CUTLER-HAMMER INC	Y	N	N
DAEWOO HEAVY INDUSTRIES, LTD	N	N	Y
DAIKIN INDUSTRIES LTD	N	N	Y
DAIKYUNG	N	N	Y
DANFOSS	N	N	Y
DAVIDSON & CO.LTD.	Y	N	N
DAYTON	N	N	Y
DEAN BROTHERS	Y	N	N
DEBOTHEZAT FAN	Y	N	N
DELAVAL-IMO	Y	N	Y
DELTA ROCKWELL	Y	N	Y
DEMCO INC	Y	N	N
DEMING PUMP	Y	N	N
DIGITAL MARINE ELECT	Y	Y	N
DOERR	N	N	Y
DOVER NORRIS	Y	N	N
DRAKE	Y	N	N
DYNALEC	Y	N	N
ECM PROD INC	Y	N	N
EDWARDS/SMITH	Y	N	N
EIMCO CORP.	Y	N	N

MANUFACTURER	Company A	Company B	Company C
ELECTRO-NAV	Y	N	N
ELLIOTT	Y	N	Y
ENGLEHARD IND	Y	N	N
ESTERLINE ANGUS	Y	N	N
FACET ENTERPRISE	Y	N	N
FALK	N	Y	N
FEDERAL PACIFIC	Y	N	N
FEECON CORP	Y	N	N
FISHER	Y	N	Y
FLAKT	Y	Y	N
FLO-TORK	Y	N	N
FOSTER	Y	N	N
FOXBORO TRANSSONICS	Y	N	Y
FREDICK IRON & STEEL	Y	N	N
FUJI HEAVY INDUSTRIES	N	Y	N
FUJITA SEISAKUSHO	Y	N	N
FUKUSHIMA LTD	N	Y	N
FUNKE	Y	N	N
FURUNO FAX	Y	Y	N
GADELIUS/HOWDEN	Y	N	N
GARDNER DENVER	Y	N	N
GAYLORD EAST	Y	Y	Y
GENERAL OZONE CO.	Y	N	N
GENERAL REGULATOR	Y	N	Y
GIMPEL MACH. WK. INC	Y	N	N
GRAHAM MANUFACTURING CO.	N	N	Y
GROUSE HINDS IND	Y	N	N
HAMMOND MACHINERY	Y	N	N
HAMWORTHY	N	Y	N
HANKINSON CORP	Y	N	N
HARRISON RADIATOR	Y	N	N
HAYWARD MEMARCO	Y	N	Y
HEISHIN	N	N	Y
HENSCHEL CORP	Y	N	Y
HILLS MCCANNA VALVES	N	N	Y
HOKUSHIN	N	N	Y
HOSE-MCCANN	Y	N	Y
HOSHIZAKI	N	N	Y
HUSSMAN	Y	N	N
HYDE PROD	Y	N	N
IMO	Y	N	Y
INDUSTRIAL GRADE	Y	N	N

MANUFACTURER	Company A	Company B	Company C
INGERSOLL RAND	Y	N	N
INNERSPACE TECH.	Y	N	N
INTECH	N	Y	N
ITT	Y	Y	Y
J E LONERGAN	Y	N	N
J. BROLICH CO.	N	N	Y
JAPAN RADIO CO	Y	Y	N
JERED IND. INC.	Y	N	N
JERGUSON GAGE &VALVE	Y	N	N
JOHNSON PUMP CO	Y	N	N
JORDAN VALVE	Y	N	N
JOTRAN	N	N	Y
JOY MANUFACTURING	Y	N	N
KALENBERG	N	N	Y
KASON HDWRE. CO.	Y	N	N
KATO ENGINEERING	Y	N	N
KELLER	Y	N	N
KERNEY	N	Y	N
KEYSTONE VALVE, USA	Y	N	Y
KING ENGINEERING	N	N	Y
KOCKUMATION	N	N	Y
KOKOSHA	N	N	Y
KRUPP ATLAS	Y	N	N
KURIMOTO IRON WORKS	Y	N	N
LAKE SHORE	Y	N	Y
LANGIAL ELECTRIC CO	Y	N	N
LAWLESS DETROIT	Y	N	N
LESLIE	Y	N	Y
LIDGERWOOD	N	N	Y
LIMITORQUE CORP	Y	N	N
LINCOLN	Y	Y	N
LOUIS ALLIS	Y	N	N
LUNKENHEIMER	N	N	Y
LYNN ELLIOTT	N	N	Y
MAN B&W DIESEL	N	Y	N
MANNING & LEWIS ENGR	Y	N	N
MARICOM	N	N	Y
MARINE MOISTURE CNTL	Y	N	Y
MARKET FORGE	N	N	Y
MASECO	Y	N	N
MATSUI COMMERCIAL	Y	N	N
MCGRAW EDISON	Y	N	N

MANUFACTURER	Company A	Company B	Company C
MCNAB INC.	Y	N	Y
MEDIA BLAST&ABRASIVE	Y	N	N
MEGATOR	Y	N	N
METRITAPE	Y	N	Y
MIDLAND ROSS CORP	Y	N	N
MIH TRIDENT	N	Y	N
MINE SAFETY APPL	Y	N	N
MISUZU	N	Y	N
MITSUI ENGINEERI	Y	N	N
MMC	Y	N	N
MOORE PRODUCTS	Y	N	Y
MORGAN PRECON	N	N	Y
MOSSER	Y	N	N
MOTOR APPLIANCE CORP	Y	N	N
MOTOROLA	Y	N	N
MOYNO	Y	N	N
MSA	Y	N	N
MUELLER	Y	N	N
MUNK	N	Y	N
NAKAKITA SEIAKUSHO	Y	N	N
NAKASHIMA MFG.	Y	N	N
NANCE	N	Y	N
NASH-HYTOR	Y	N	Y
NAVIDYNE	Y	N	N
NEW SULZER DIESEL U.S., INC.	N	Y	N
NIFE INC.	Y	N	N
NIHON KAPPA KOGYA K.K.	N	Y	N
NIIKURA KOGYO CO.	Y	N	N
NIPPON ELEVATOR IND. CO. LTD	N	Y	N
NISHISHIBA	N	Y	N
NISSIN REFRIGERATION & ENGINEERING, LTD	N	Y	N
NORDISK VENTILATOR CO. A/S	N	Y	N
NUNOTANI HAKUYO	N	Y	N
OASIS	N	Y	N
OMRON	N	Y	N
ORTMAN MILLER MACH.	Y	N	N
PACEMAKER MTRS	Y	N	N
PAUL MUNROE	Y	N	N
PAULUHN	Y	N	Y
PEABODY ENGINEERING	Y	N	N
PERKO	N	N	Y

MANUFACTURER	Company A	Company B	Company C
PHOENIX	Y	N	N
PIMA	N	N	Y
POW CON	N	Y	N
POWERS REGULATOR	Y	N	N
PREFEX CORP	Y	N	N
QUAKER CITY	N	N	Y
R.A. LISTER & CO. LTD	Y	Y	N
R.F. HARRIS	Y	N	N
R.L. DRAKE	Y	N	N
RADIO HOLLAND INC.	Y	N	N
RAYTHEON	Y	Y	Y
RCA	Y	N	N
RED FOX	Y	N	N
RELIANCE	Y	N	Y
REULAND	Y	N	Y
REXROTH	N	Y	N
RICOH CORPORATION	N	Y	N
ROBBINS & MYERS	Y	N	N
ROBERT H. WAGER	Y	N	N
ROCKWELL EDWARDS	Y	N	N
ROHRER MARINE SALES	Y	N	N
RONA & KUNZL	N	N	Y
RUCKER/PAUL MUNROE	Y	N	N
RUGGLES KLINGEMANN	Y	N	N
SAAB SCANIA	Y	N	N
SAILOR	Y	N	N
SALEN & WICANDER	Y	N	N
SAM GONG-SA	N	Y	N
SCHUTTE & KOERTING	Y	N	N
SCIENTIVIC ATLANTA	Y	N	N
SEOKWANG	N	Y	N
SERCK	N	Y	N
SESTREL	N	Y	N
SGC MACHINES	N	Y	N
SHARPLES	N	N	Y
SHIMADZU	Y	N	N
SHINKO, INC. LTD	N	Y	N
SHIPMATE NAVIGATOR APS	N	Y	N
SHOWA IND CO	Y	N	N
SIEMEN & HINSH	Y	N	N
SIEMENS	Y	N	N
SIEMENS-ALLIS	Y	N	N

MANUFACTURER	Company A	Company B	Company C
SIGMA	Y	N	N
SIMPLEX	Y	N	Y
SKF, MRC, FAF, NDH	Y	Y	N
SKF. TIMKEN, FAF	Y	Y	N
SNAP-TITE	Y	N	N
SOUTH BEND	Y	N	N
SPEICH	N	N	Y
SPERRY	Y	Y	Y
STAR TOOL & SUPPLY	Y	N	N
T.C.WILSON CO.	Y	N	N
TACO HEATERS INC	Y	N	N
TAIKO KIKAI IND	Y	Y	N
TAIYO ELECTRIC CO.	Y	N	N
TAYLOR SERVOMEX	Y	N	N
TECNIC GALI, S.A.	N	Y	N
TEEL	Y	N	N
TEIKOKU KIKAI	N	N	Y
TERASAKI ELECT	Y	Y	N
TERRY	Y	N	N
THE TRANE CO	Y	N	N
THERMO KING CORP	N	Y	N
THERMXCHANGER	Y	N	N
TODD, CEA	Y	N	N
TOKO SEIKI CO LTD	Y	N	N
TOKYO KEIKI CO. LTD.	N	Y	N
TOSHIBA CORP	Y	N	N
TRIFON INC	Y	N	N
TRIMBLE NAVIGATION	N	Y	N
U.S. ELECT. MOTORS	Y	N	N
ULTRA DYNAMICS CORP	N	Y	N
UNIDYNAMICS	Y	N	N
UNITOR SHIPS SERVICE AS	N	Y	N
VALAD ELECTRIC HEATING CORP	N	N	Y
VICKERS"ELECTRIC CO"	Y	N	N
VICTOR PYRATE	Y	N	N
VIKING PUMP	Y	N	N
VITA MOTIVATOR	Y	N	N
VOLCANO CO. LTD	N	Y	N
WALLACE & TIERNAN	N	N	Y
WALTER H. EAGAN	Y	N	N
WALTER KIDDE	N	N	Y
WARREN	Y	N	Y

MANUFACTURER	Company A	Company B	Company C
WATERCRAFT AMERICA, INC.	N	Y	N
WAUKESHA BEARINGS	Y	N	N
WEKSLER	Y	N	Y
WESTERBEKE	Y	N	Y
WESTERN GEAR	Y	N	N
WESTFALIA	Y	N	N
WESTINGHOUSE	Y	N	Y
WHITLOCK	Y	N	N
WILDEN	Y	N	N
WILDON PUMP & ENGINEERING CO	N	Y	N
WILSON WALTON	Y	N	N
WOODWARD GOVERNOR	Y	N	N
WORTHINGTON	Y	N	Y
YAMASHINA SEIKI COMPANY LTD	N	Y	N
YARWAY	N	N	Y
YOKOGAWA	Y	N	N
YORK MARINE	Y	N	Y

APPENDIX D
PROPOSED AND ACHIEVED TIME LINES

The main differences between the proposed original time line and the achieved time line are for the following tasks:

1. DATE AND SHIPPER MODIFICATIONS

The development and debugging of the DATE and SHIPPER prototype (Version 1.0) have been delayed by the subcontractor Systems Exchange. This company, which submitted the lowest bid, was initially selected by the SOCP executive committee for DATE and SHIPPER program development. However, Systems Exchange had difficulty replacing the first programmer Mr. Fousch who left the company. As a result, the SOCP decided to change the software consultant for the modifications and upgrades. After a long bidding process, DCC was selected to implement the changes and to develop SPIN/SHIPS' RAM.

2. DATE INTERFACES

Code development of interface modules for ARCO and Sea Land was postponed since both companies were upgrading and integrating their programs related to DATE. They requested that we wait until the completion of their upgrades.

3. SPIN / SHIPS' RAM

Specification development was delayed due to DATE and SHIPPER delays. Specifications were adjusted by combining the common modules of SPIN and SHIPS' RAM leading to dual use. Source codes of SPIN and SHIPS' RAM prototypes (Versions 1.0 Beta) are currently identical. SPIN runs with personal Oracle on a PC whereas SHIPS' RAM runs with Oracle 7 in a workstation environment with more data manipulation and pooling functions. Subcontracting for these two programs was delayed since the quoted price slightly exceeded the budgeted amount. Consequently, we had to request additional funding and had to go through the approval process.

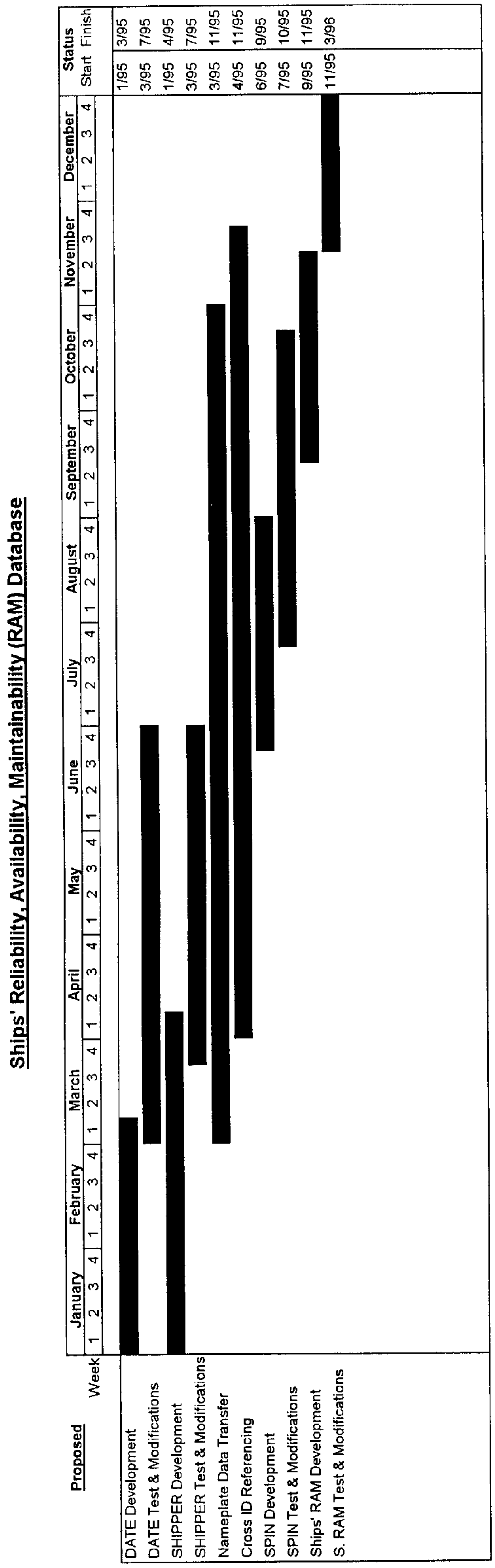

Figure 57. Original Proposed Time Line

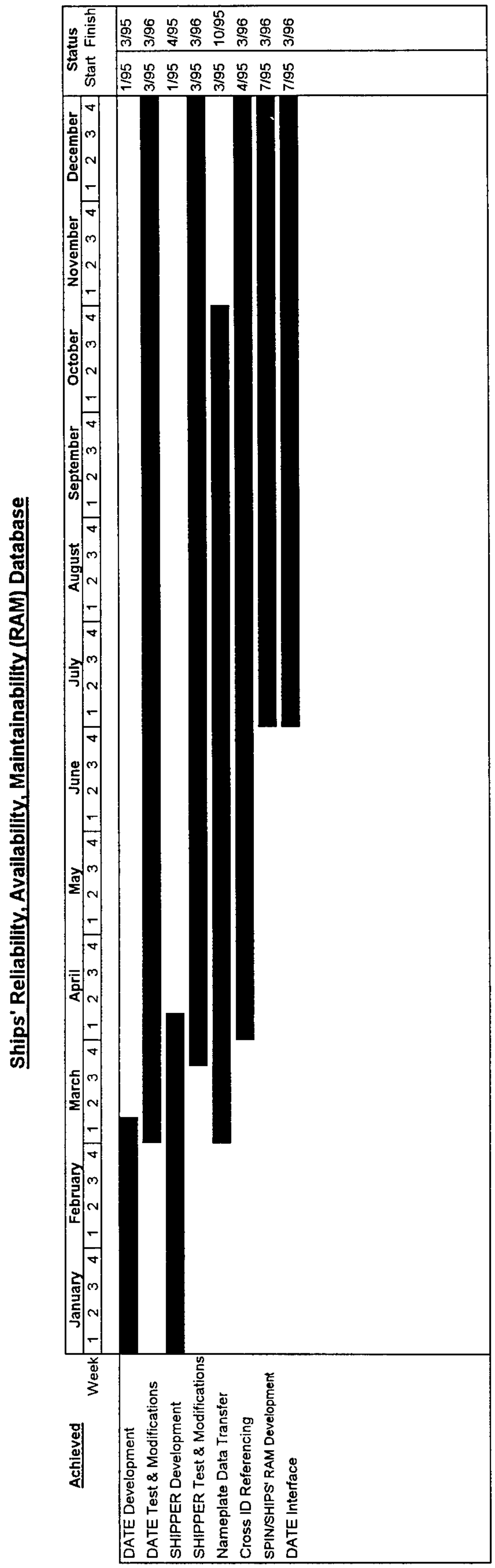

Figure 58. Achieved Time Line